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Environmental and Safety
Engineering Staff
Ford Motor Company

The American Road
Dearborn, Michigan 48121

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Washington, DC 20460

Attention: Public Docket No. A-91-46

The purpose of this communication is to supply additional information and data to supplement that outlined in our October 3 and 28, 1991 letters concerning Ethyl Corporation's MMT waiver request. This communication contains the addition emission component (HEGO, catalyst, fuel injector) test data, a discussion and analysis of test-to-test data variability comparing Ford and Ethyl test results, a Ford analysis of Ethyl's test data, and particulate emission test data through 105,000 miles and information to demonstrate the representativeness of the Ford driving cycle.

The additional HEGO and catalyst tests on clear-fueled Escort #317 demonstrated a similar increase in HC levels with MMT-contaminated components as seen on clear-fueled Escort #315. The only reason the HC levels increase must be the impaired function of these components due to the MMT. The variability in the Ford test data is no different than that seen on Ethyl test vehicles. The variability between tests on the same model types from Ethyl's test fleet is as high as 0.36 grams per mile (gpm) HC on MMT-fueled vehicles, and 0.27 gpm HC on clear-fueled vehicles. These large variabilities preclude drawing the conclusion with any high degree of confidence which Ethyl had drawn concerning the effect of MMT on HC levels. The Ford analysis of Ethyl's test data shows twice the increase in HC levels as compared to Ethyl's calculation.

We believe the Ford data are more representative than that produced in the Ethyl program for the following reasons. The Ford mileage accumulation cycle averaged 54.8 mph and was driven on public rural roads and expressways within the State of Michigan. It should be noted that the EPA highway cycle used for fuel economy and NOx measurements averages 48 mph and was structured to represent 45% of typical driving based on road studies in the mid-1970s. Further, DOT highway statistics and Ford studies corroborate that rural/country and expressway, combined, represent approximately 40-50% of U.S. driving. Thus, we believe that the Ford test cycle represents a significant portion of U.S. driving and that the deleterious effects of MMT on the emission control systems also must be considered significant. Moreover, because the Ford durability program produced results which were parallel to the problems encountered on in-use Canadian vehicles, it is clear that it is more representative than the program conducted by the waiver applicant.

Additionally, the Ford program included trucks with higher power absorption and fuel consumption typical of full-size products. The Ford program included fuel with commercially-available detergent additives required under EPA certification protocol for mileage accumulation. Finally, unlike the Ethyl program which scheduled replacement of the fuel injectors at approximately 50,000 miles, the Ford program considered that the injectors might be affected by the MMT additive, allowing them to remain in the vehicle for the duration of the program. Subsequent component evaluation corroborated that such deposits did contribute to the increase in emissions of the MMT-based vehicles.

Ethyl correctly states that it bears the burden of proof under Section 211, and that the party opposing the waiver must present competent contradictory evidence. In fact, the record clearly demonstrates that Ford has presented documents and data which causes Ethyl to fail to prove its assertion beyond a preponderance of the evidence. In addition, under Section 211(c)(1), under which EPA can issue regulations prohibiting a fuel or fuel additive from entering into the stream of commerce, if it will impair to a significant degree the performance of any emission control or device, provides an independent basis upon which to reject Ethyl's waiver request. Clearly, the record shows that MMT will significantly impair the performance of emission controls or devices.

Sincerely,

David L. Kulp
Manager, Fuel Economy
Planning & Compliance

Enclosures

ENCLOSURES TO FORD MOTOR COMPANY'S NOVEMBER 22, 1991 COMMENTS ON ETHYL CORPORATION'S WAIVER REQUEST TO ADD MMT TO GASOLINE

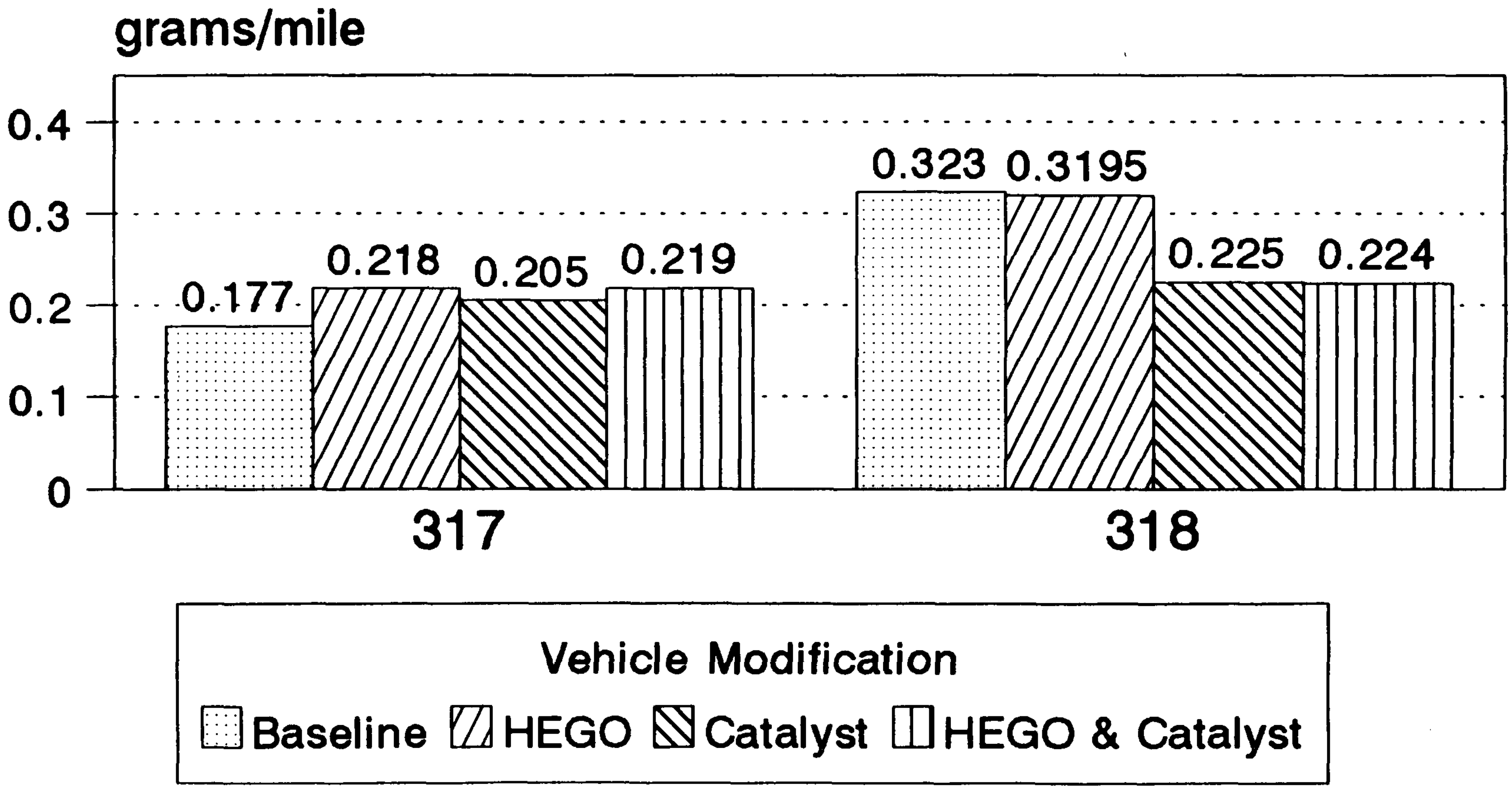
- Ford Emission Component Test Data from Escort and Explorer Vehicles
- The Representative Ford Driving Cycle
- Discussion of Test-to-Test Data Variability
- Ford Analysis of Ethyl's Test Data
- Particulate Emission Results from Escort and Explorer Vehicles

EMISSION COMPONENT TEST DATA ANALYSIS

Attached are the additional, and final, test data from Escort #317 which was incomplete in the Ford October 28, 1991 submission. The results on clear-fueled vehicle #317 show the same trend as clear-fueled Escort #315. This trend is a large increase in tailpipe HC levels when MMT-contaminated HEGO sensors and catalysts from MMT-fueled vehicles are installed and tested on clear-fueled vehicles.

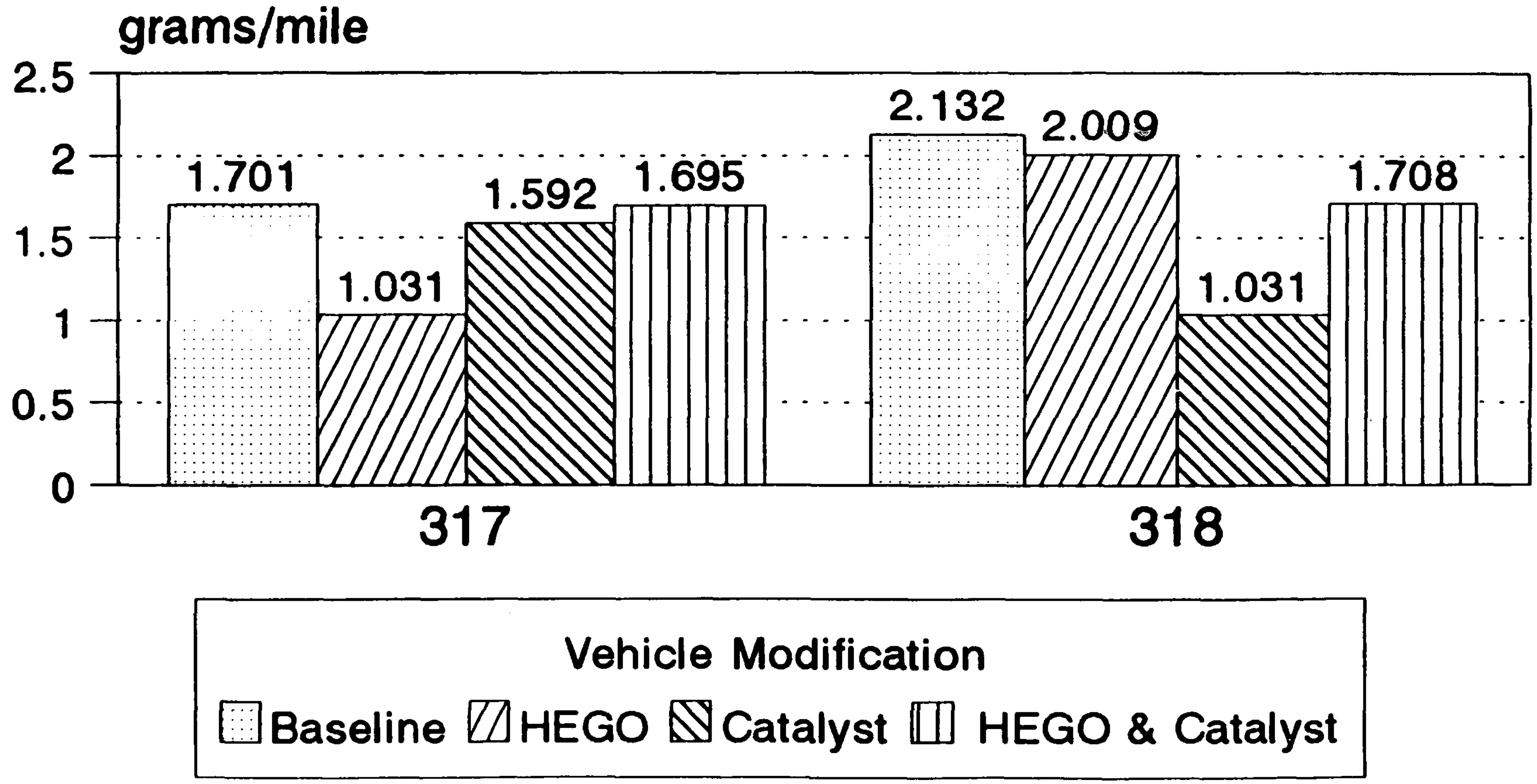
Further testing on MMT vehicle #306 with new fuel injectors installed after 100,000 miles lowered the HC level from 0.66 gpm to 0.28 gpm. The HC levels of clear vehicle #305 with old and new injectors did not show deterioration. This clearly demonstrates how MMT has contaminated the fuel injectors causing poor fuel-air distribution to the cylinders resulting in high HC levels. An analysis of the deposits on the fuel injectors removed from vehicle #306 indicates the presence of MMT. The effect of MMT on engines and emission control devices appear to be erratic. The Explorer vehicles have higher feedgas HC levels as a result of MMT indicating fuel injector contamination, whereas the Escort vehicles had greater contamination of their emission control devices resulting in higher HC levels. The mileage intervals at which point MMT causes the greatest increase in HC levels varies from vehicle type to type. However, after 100,000 miles, both Escort and Explorer MMT-fueled vehicles demonstrated much higher HC levels than the clear-fueled vehicles. It is believed that the Explorers, after 100,000 miles, demonstrated the greater HC increase than the Escorts because of the much higher consumption of MMT on the Explorers. Also, it is believed that the greater variability in HC levels on the MMT-fueled Explorers after 50,000 miles is a result of the erratic effect MMT has on the performance of fuel injectors. It is clear from the test data from vehicle #306 that new fuel injectors substantially improved HC levels. If Ford had changed fuel injectors on these vehicles after 50,000 miles, the adverse effect of MMT would have been masked at higher mileage points. Changing fuel injectors at 50,000 miles is clearly the wrong thing to do.

HC Tailpipe Emissions
Escort Fleet



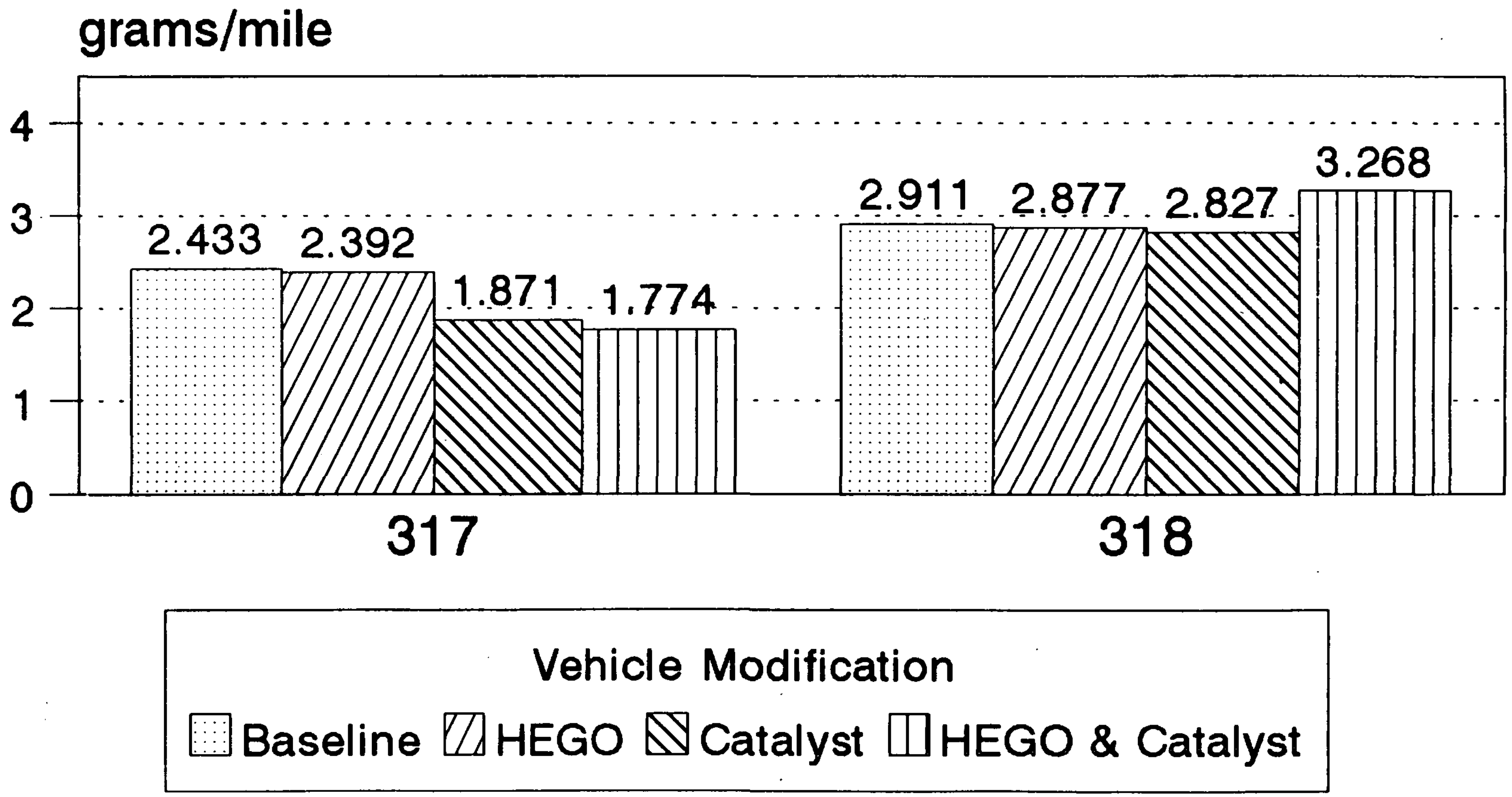
317- Non-MMT Fuel
318- MMT Fuel

HC Feedgas Emissions
Escort Fleet



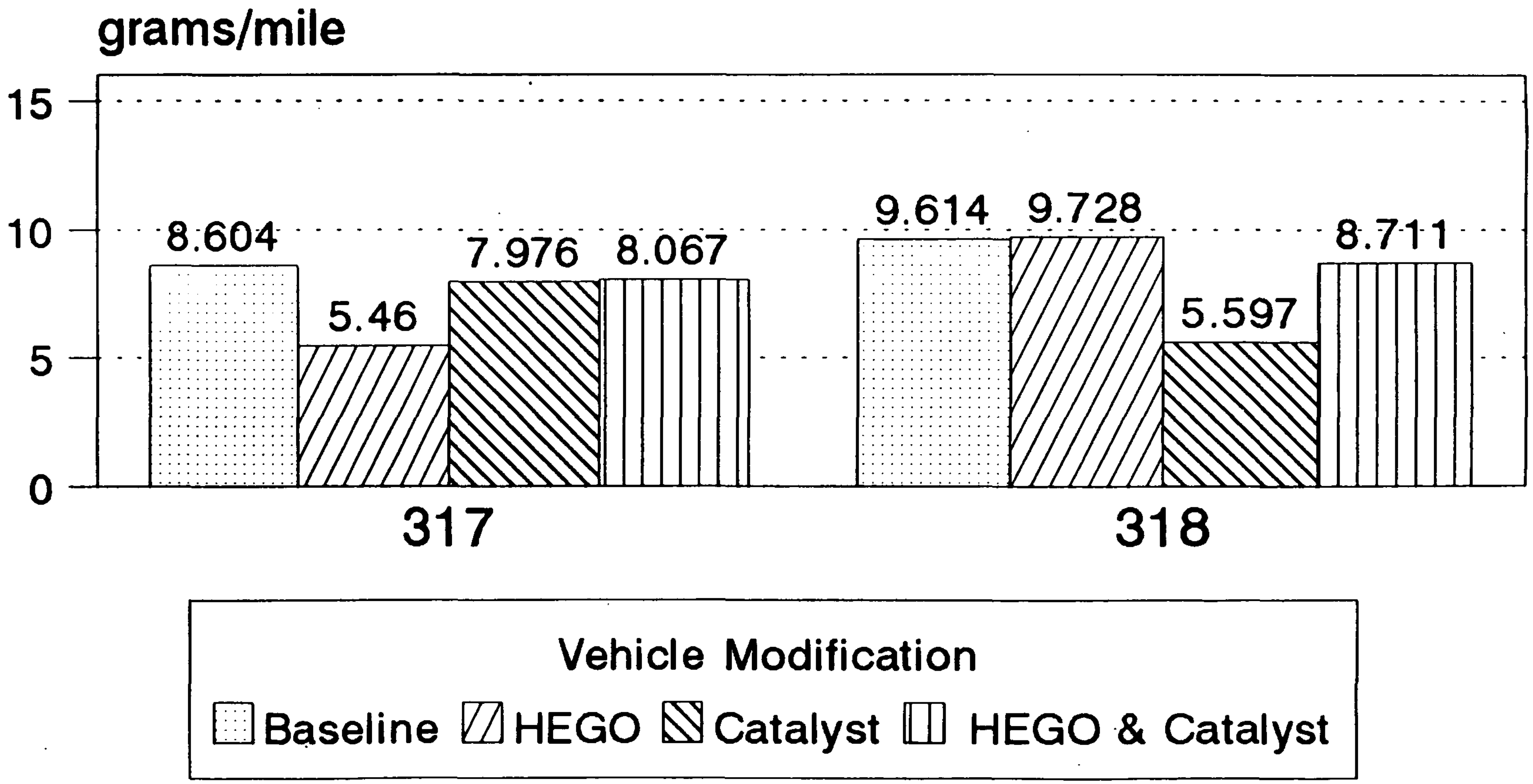
317- Non-MMT Fuel
318- MMT Fuel

CO Tailpipe Emissions
Escort Fleet



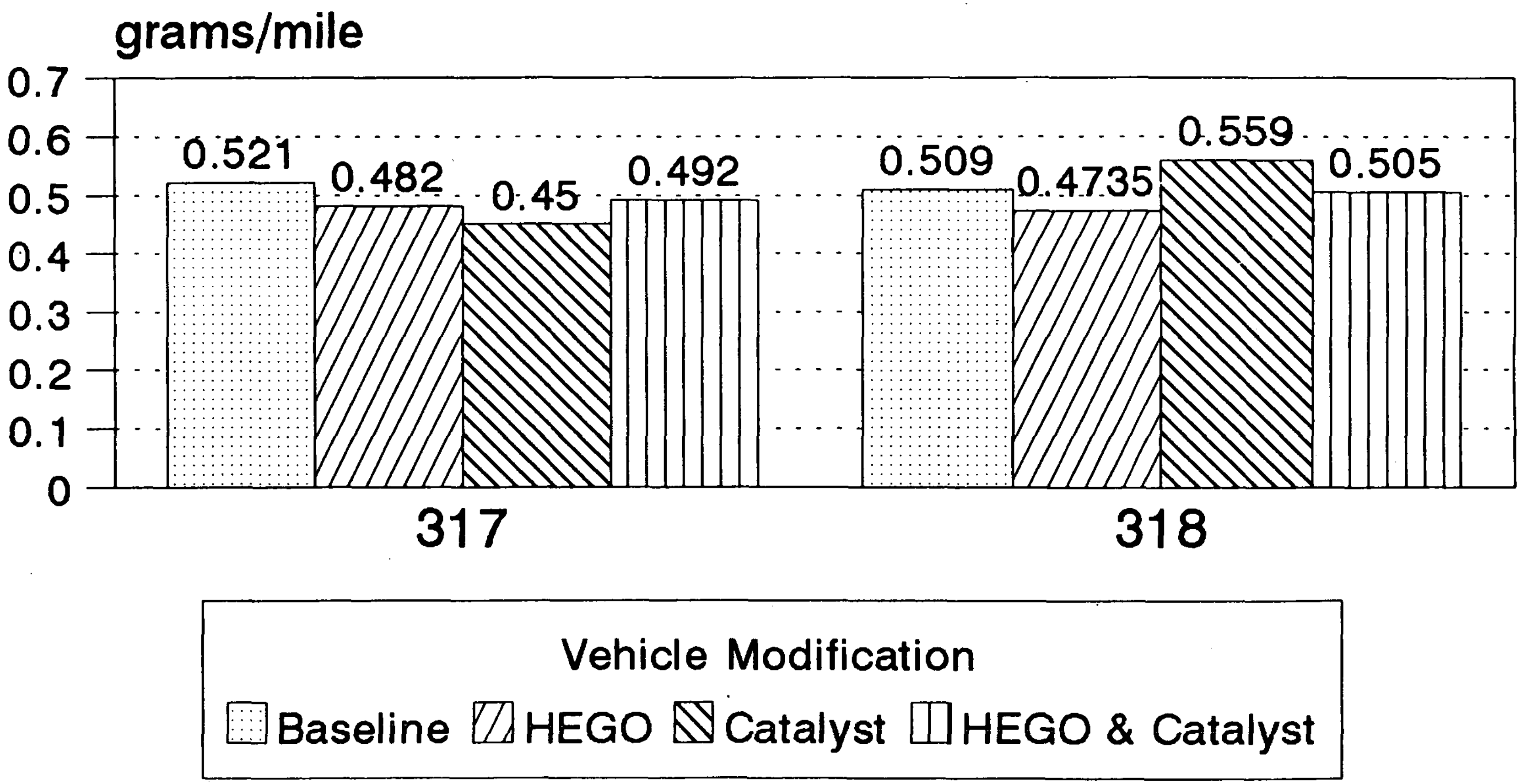
317- Non-MMT Fuel
318- MMT Fuel

CO Feedgas Emissions
Escort Fleet



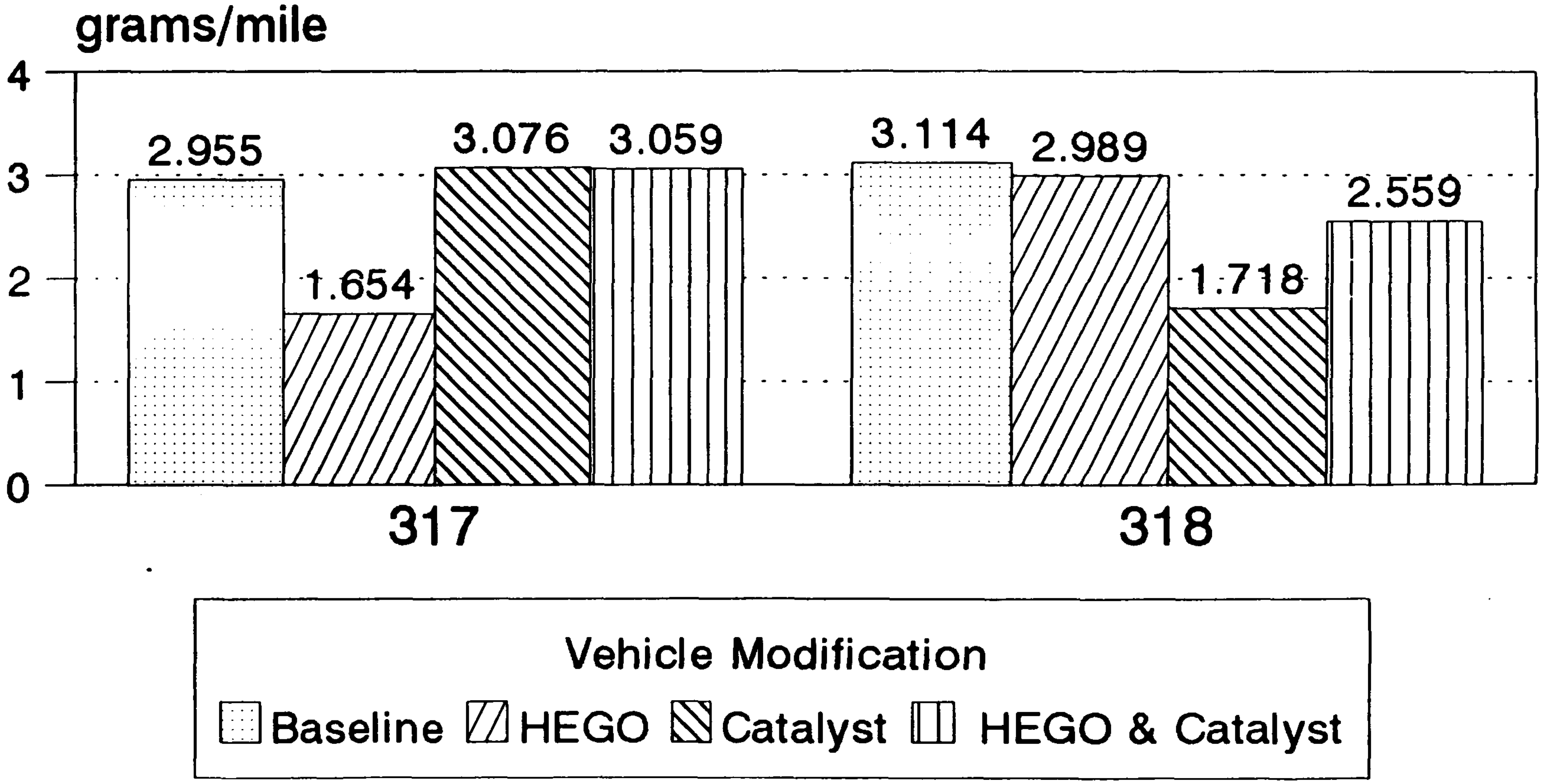
317- Non-MMT Fuel
318- MMT Fuel

NOx Tailpipe Emissions
Escort Fleet



317- Non-MMT Fuel
318- MMT Fuel

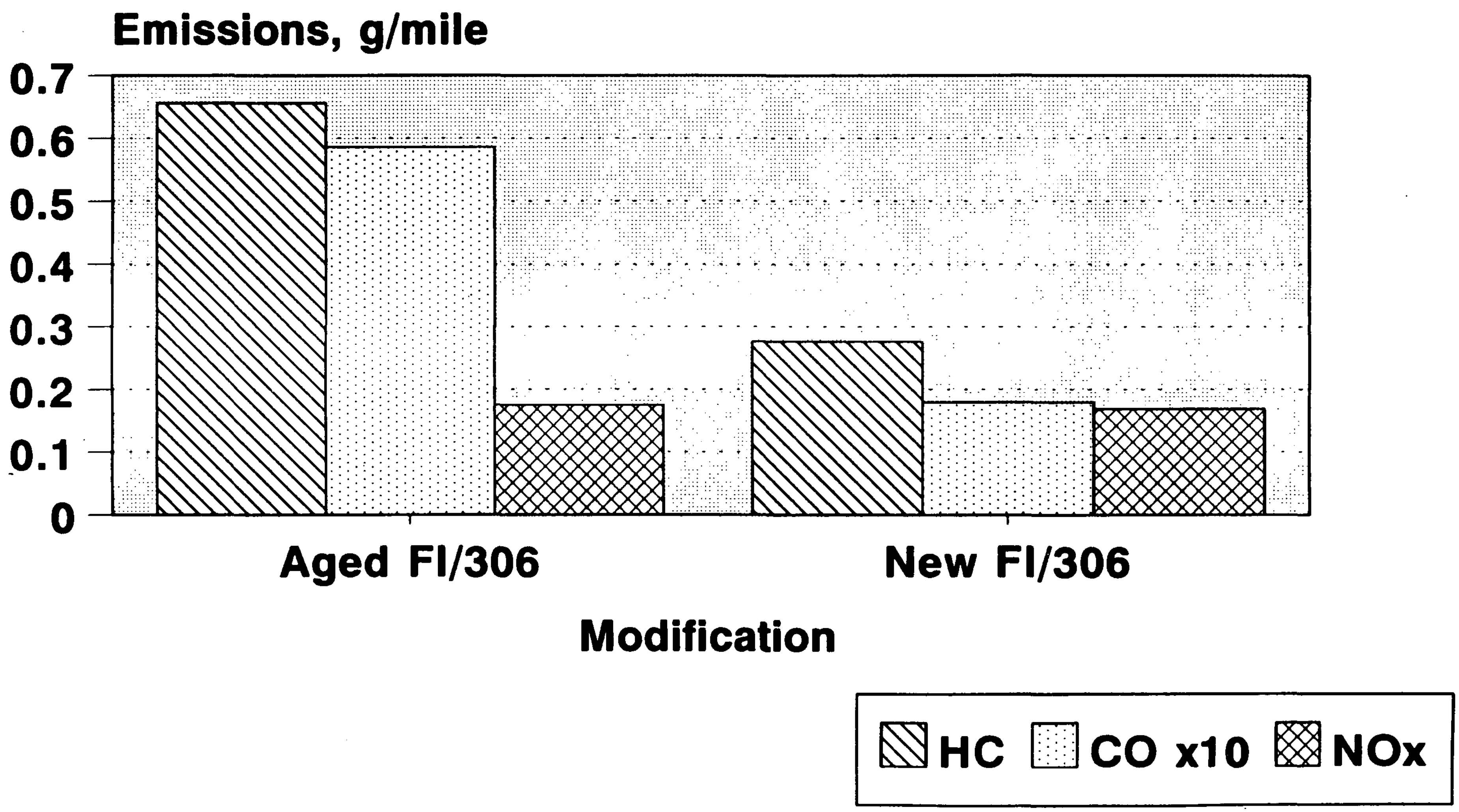
NOx Feedgas Emissions
Escort Fleet



317- Non-MMT Fuel
318- MMT Fuel

EXCHANGE FUEL INJECTORS

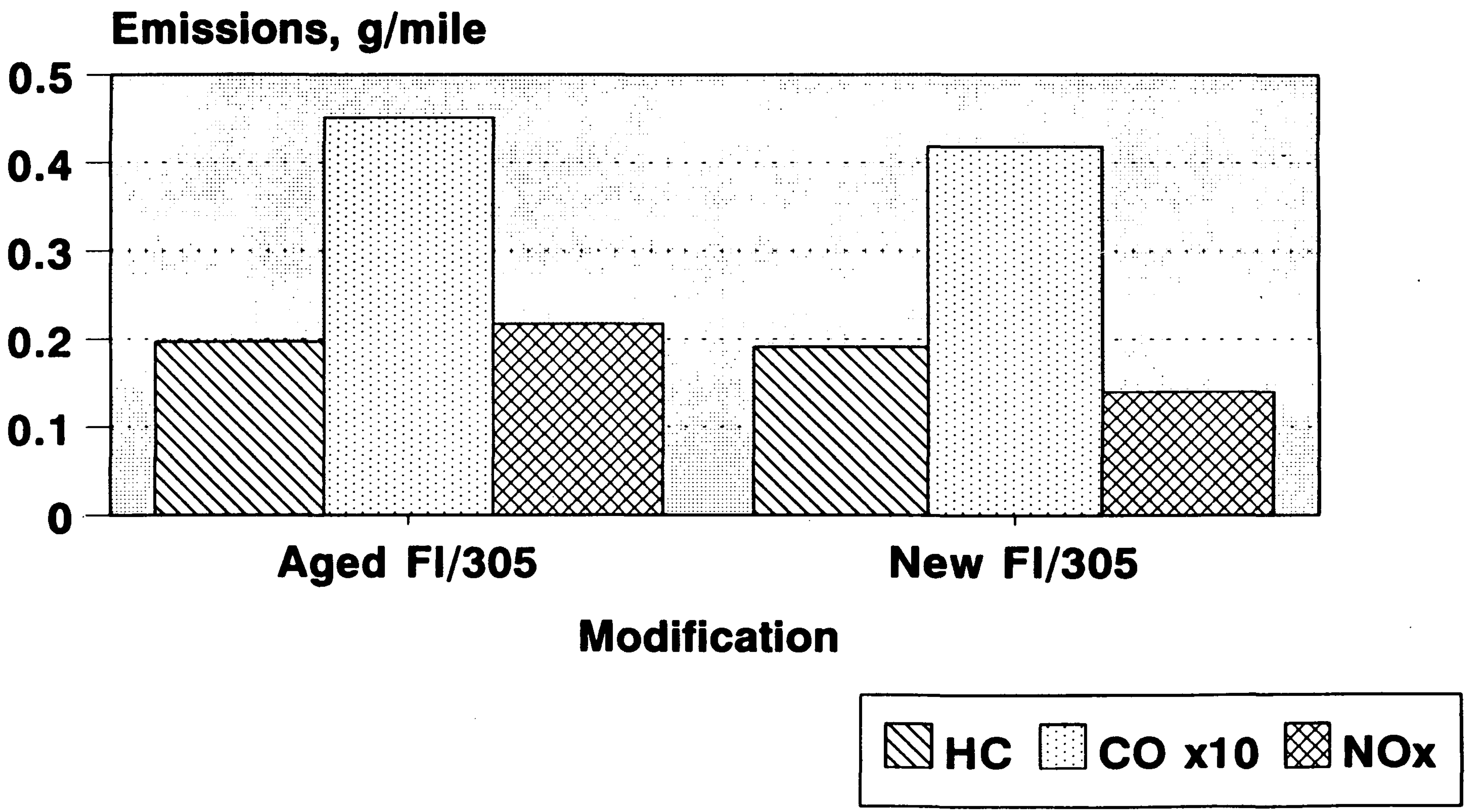
Vehicle #306



Aged FI @105,000 miles
100,000 miles MMT Exposure

EXCHANGE FUEL INJECTORS

Vehicle #305



Aged FI @105,000 miles
100,000 miles MMT Exposure

THE REPRESENTATIVE FORD DRIVING CYCLE

The driving cycle used by Ford resulted in an average speed of approximately 54.8 mph. This average speed is similar to the 48.2 mph average speed used by EPA during its fuel economy highway cycle (40 CFR, Part 600, App. 1). This cycle is weighted under EPA procedures [40 CFR, Part 600.002-85(13)(c)] to represent 45% of the average or "combined" driving. The EPA highway cycle was developed in the mid-1970s (SAE 740592, attached) to typify non-urban operation when characterizing the fuel economy of automobiles.

Review of Table VM-2 from DOT's Highway Statistics for 1988 confirms that Rural operation and Urban Interstate/Expressways combine to represent more than 55% of the U.S. VMT. Combining these data with that contained in Table VS-1 in the DOT report, indicates that average speeds for all highways and major Rural collectors and arterials, average well over the 54.8 mph found in the Ford program.

Ford conducted a 1989 study of 1,000 owners of Tempo-sized vehicles to determine typical operating routes and conditions. That survey found that 30% of the time, vehicles operated on expressways and 20% in country areas. A chase car survey was employed to determine the average speeds for these two modes, resulting in 43 mph for country and 57 mph for expressway. Thus, the Ford program further demonstrated that the Ford route was fully representative of actual driving for these products.

In addition, the 45-55% of U.S. VMT which represents rural/expressway driving is well over the 33% threshold factor used by EPA for other emission/fuel economy regulations. If it is expected that more than 33% of a carline within an engine system combination may be equipped with an item (whether that item is standard equipment or an option), then the weight of that item or the installation of the options which may affect emissions must be installed on all test vehicles of that carline, within an engine system combination (Reference: 40 CFR 86.085-24). EPA regulations require that if its representative of more than 33% of the population, then it is representative of the entire population. Hence, the driving cycle used by Ford which represents the way more than 33% of typical operation must, by EPA's criteria, be considered significant.

740592

Passenger Car Fuel Economy During Non-Urban Driving

Thomas C. Austin, Karl H. Hellman, and C. Don Paulsell
Environmental Protection Agency

AN EXTENSIVE DATA BASE on a representative and consistent test procedure is required to determine trends in passenger car fuel economy or to rank various models. The use of the 1972 Federal Test Procedure (FTP) has provided one such data base but it is recognized that the FTP primarily represents urban driving. To more fully characterize the fuel economy of passenger cars, a cycle representing nonurban operation has been developed for use in conjunction with the FTP.

CYCLE DEVELOPMENT

The first step in the development of the nonurban or "highway" cycle was to establish criteria for the cycle. To make the cycle representative of nonurban operation, it was decided that it should:

1. Reflect driving on a variety of nonurban roads.
2. Be self-weighting (that is, have the correct proportion of travel on each road type).
3. Be of a length equal to the average trip in a nonurban area.
4. Preserve the non-steady-state nature of real-world driving.
5. Have an average speed and number of stops per mile equal to that experienced in nonurban driving.

A review of the literature and consultation with several organizations familiar with fuel economy testing indicated that no cycles were available that met the criteria outlined above.

To fulfill the established criteria it was decided to take the following steps:

1. Identify the proportion of nonurban driving done on all major nonurban road types and determine the average nonurban trip length.
2. Select road routes to cover all major nonurban road types.
3. Drive an instrumented test car over the various types of nonurban roads recording the speed-versus-time history of the vehicle.
4. Reduce the data to characteristic parameters for each type of road.

ABSTRACT

The use of fuel economy data from the Federal Test Procedure (FTP) has provided a substantial amount of data on the fuel economy of passenger cars in urban driving conditions. Since the FTP does not represent the type of driving done in rural areas, especially on highways, a driving cycle to assess highway fuel economy was a desirable supplement to the FTP.

The new Environmental Protection Agency (EPA) "highway" cycle was constructed from actual speed-versus-time traces generated by an instrumented test car driven over a variety of nonurban roads and highways. This cycle reflects the correct proportion of operation on each of the four major types of nonurban roads and preserves the non-steady-state characteristics of real-world driving.

The average speed of the cycle is 48.2 mph and the cycle length is 10.2 miles, close to the average nonurban trip length.

Preliminary vehicle tests show that rotary and conventional engine-powered vehicles achieve approximately the same ratio of highway fuel economy to urban (FTP) fuel economy. Various unconventional engine-powered vehicles show different values for the ratio of highway to urban fuel economy. The continued use of the highway cycle will establish a data base which, when used in conjunction with FTP data, will allow better estimates of both fuel economy and exhaust emission trends.

5. **Using the most representative portions of the speed-versus-time traces collected, construct a cycle that contains the proper proportions of distance for the various nonurban road types and is of the proper nonurban trip length.**

NONURBAN DRIVING STATISTICS - The initial step in the development plan was accomplished by reviewing Refs. 1 and 2. The first defines an urban area as an incorporated or unincorporated place with a population of 5000 or more (1)*. Nonurban areas are all places with populations of less than 5000. The roads in the nonurban areas are segregated into four major types: Principal arterials, minor arterials, collectors, or locals.

Principal arterials form the statewide and interstate highway network. An example of a principal arterial road is a limited access interstate highway. Major nonlimited access statewide or interstate highways also qualify. Essentially all population centers of over 50,000 people are served by the principal arterial system.

The minor arterial system consists of paved highways that link smaller cities and large towns.

The collector system consists of a paved road network that is generally intracounty rather than statewide. Collectors link small towns and business centers.

The local system consists of roads that link other roads rather than population centers. They often provide access to private property. While most local roads are not paved, the largest proportion of the miles driven on local roads is on those that are paved.

Although only 3.7% of the nonurban road miles in the United States are principal arterials, they handle 39.5% of the nonurban mileage driven. The local roads which make up 68.4% of the nonurban road length handle only 14.2% of the nonurban mileage driven.

Nonurban trip length information was obtained from Ref. 2 for unincorporated and incorporated places. Although "unincorporated place" is not the same definition used in Ref. 1 for nonurban areas, it is the authors' judgment that the nonurban areas defined by Ref. 1 and the "unincorporated places" of Ref. 2 are essentially identical. The average trip length for unincorporated areas was reported to be 9.9 miles.

Table 1 shows the relative lengths of each of the four major nonurban roads and the portion of nonurban vehicle miles traveled (VMT) that occur for each type. The data used to make up Table 1 are from Ref. 1.

USE OF THE TEST CAR - The vehicle used to collect data in this program was a 1971 Ford Ranchwagon with 429 CID-4V engine, three-speed automatic transmission, and a 2.75 ratio rear axle. This vehicle had been previously instrumented for a study of vehicle operation and driving profiles. The instrumentation included a manifold vacuum transducer, digital timer (seconds), driveshaft torquemeter, and driveshaft speed pickup. The signals from the driveshaft were scaled and recorded on a strip chart moving at a rate of 4 in/min to produce the same time base as strip charts commonly used to display the FTP driving cycle. All of the instrumentation was calibrated and checked on a chassis dynamometer to verify true speed and torque readings. The vehicle contained a static inverter power supply to provide 120 V, 60 Hz electricity. This supply was used on all calibrations and testing.

*Numbers in parentheses designate References at end of paper.

Table 1 - Nonurban Roads

Road Type	Total Nonurban Road Length, %	Nonurban VMT, %
Principal arterial	3.7	39.5
Minor arterial	5.5	22.4
Collector	22.4	23.9
Local	68.4	14.2

Table 2 - Average Observed Characteristics

Road Type	Average Speed, mph	Stops/mile	Speed Deviations/mile
Principal arterial (A)	57.16	0.0100	0.070
Minor arterial (B)	49.42	0.0575	0.439
Collector (C)	45.80	0.1260	0.484
Local (D)	39.78	0.2360	0.598
Composite	49.43*	0.0800	0.327

$$\text{*Composite speed} = \frac{1}{(0.395\, V_A + 0.224\, V_B + 0.239\, V_C + 0.142\, V_D)}$$

The true road speed was checked against the vehicle speedometer to permit a quick calibration of the recorder on the road. A panel meter which indicated driveshaft speed also facilitated a third check on true speed and calibration stability. Calibration checks indicated good stability throughout the entire program.

The vehicle was driven over 1050 miles of nonurban roads in the Michigan-Ohio-Indiana area to generate the speed-versus-time traces that were used to construct the composite nonurban cycle. The principal arterial mileage used to develop the cycle was taken from driving done only in Ohio where the official speed limit had been 55 mph for several months. Three different drivers were used during the data collection phase. Drivers were instructed to flow along with traffic, that is, to pass as many cars as passed them. An observer was present on each trip to monitor the equipment and to make notes pertaining to the speed-versus-time trace generated by the vehicle.

CYCLE CONSTRUCTION - To facilitate the analysis of the charts, they were properly identified according to route number and were reviewed and verified by the route observers. They identified route segments according to type of road, determined which segments represented urban (those having a

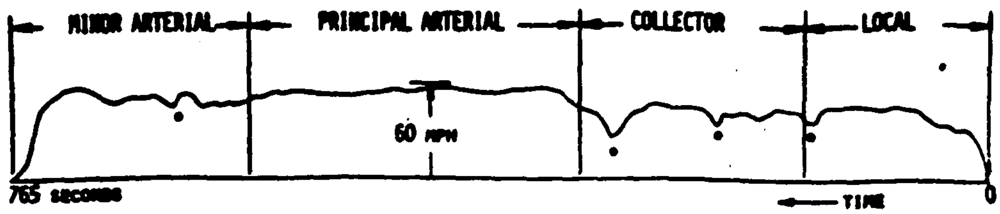


Fig. 1 - EPA nonurban "highway" driving cycle

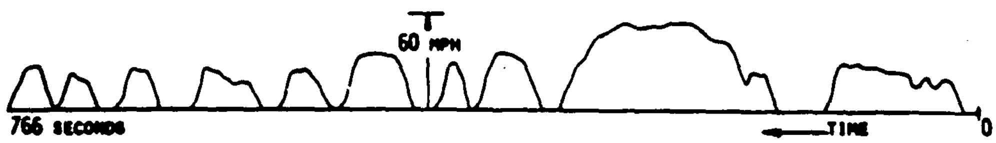


Fig. 2 - EPA urban driving cycle (LA4)

Table 3 - Nonurban Cycle Characteristics (Proposed and Actual)

Road Type	Average Speed, mph	Speed Deviation/ Mile	Stops/Mile	Length, miles
Principal arterial	(57.2)* 56.1	(0.070) 0	(0.0100) One stop for entire cycle	(3.91) 3.96
Minor arterial	(49.4) 48.2	(0.439) 0.397	(0.0575)	(2.22) 2.52
Collector	(45.8) 43.8	(0.484) 0.952	(0.1260)	(2.37) 2.10
Local	(39.8) 40.7	(0.598) 0.617	(0.2360)	(1.41) 1.62
Composite	(49.4) 48.2	(0.327) 0.391	(0.08) .098	(9.9) 10.2

*Numbers in parentheses indicate the proposed goal.

population above 5000) driving and deleted the urban segments. Data reduction consisted of tabulating route speeds at 15 s (1 in) intervals to determine the maximum, minimum, and average segment speeds. Total segment time, distance, number of stops, and number of major speed deviations per mile for each segment were calculated. A speed deviation was defined as an excursion greater than ±5 mph from a line connecting end-point velocities on 6 in intervals (1.5 min) of the entire segment. These data, presented in Table 2, were compiled from all of the charts and the average characteristics were determined for each road type.

The next step in the cycle construction process was to locate segments of the actual speed-versus-time traces that would approximate these average characteristics and would produce a composite cycle roughly 9.9 miles long. This meant, for example, that a section of strip chart from operation on a minor arterial had to be located having an average speed of 49.42 mph, containing 0.0575 stops and 0.439 speed deviations/mile, and measuring 2.22 miles in length.

Segments of the strip charts that came close to meeting the criteria shown in Table 2 were then checked for their compatibility with each other. It was necessary to arrange the various segments in such a way that the vehicle speed profile at the end of one segment would match the vehicle speed profile at the beginning of the next segment. The composite cycle, composed of four segments taken from the strip charts, is shown in Fig. 1. The stars indicate the location of the speed deviations. Two seconds of idle occur at the beginning and the end of the cycle to account for the portion of idle operation that analysis of the strip charts indicated would be experienced in this length of nonurban driving.

Fig. 2 is a record of the first 766 s of the "LA4" urban driving cycle used for the FTP. This comparison has been illustrated to show the dramatic differences in the driving patterns. Compared to the nonurban cycle, the urban cycle has less than half the average speed and nine times as many stops in the same amount of time.

The final step in the cycle development process was to run the cycle on a chassis dynamometer. A variety of vehicles ranging from low-powered economy cars to higher performance vehicles were driven over the cycle in the EPA laboratory and no problems were encountered. All accelerations and decelerations were met and the trace was assessed by the drivers to be more easily driven than the LA4.

Copies of the new cycle were then made available to interested parties. Several organizations that used the nonurban driving cycle reported that the initial acceleration and final deceleration rates were high enough to sometimes cause belt slippage on dynamometers with belt-driven inertia weights. Calculations show that the rates were about 4.0 mph/s. To facilitate running the nonurban cycle on belt-driven dynamometers without causing abnormal slippage and wear, the first 10 s and last 20 s of the cycle were modified slightly to reduce the acceleration and deceleration to less than 3.3 mph/s. These modifications have no significant effect on the fuel economy a vehicle will achieve driving the cycle.

Table 3 shows the characteristics of the final version of the nonurban cycle compared to the target characteristics. The values in parentheses are the characteristics determined from the analysis of the strip charts for all 1050 miles of test car operation.

PRELIMINARY TEST RESULTS

WARMUP - To determine the effect of warmup on nonurban fuel economy, two different types of tests were run on several conventional vehicles. The first type consisted of consecutive nonurban cycles run from a cold start. The vehicle, previously parked in a 68-86°F environment for at least 12 h, was then pushed onto a chassis dynamometer and driven over the nonurban cycle four consecutive times. Fuel economy was determined for each cycle. The second type of test was run using the 1975 FTP followed by a 1 h soak as preconditioning for three consecutive nonurban cycles. Results typical of both types of warmup tests are shown in Table 4.

The data shown in Table 4 indicate that one 1975 FTP, even when followed by a 1 h delay, is sufficient to nearly stabilize a conventional vehicle for the nonurban tests. Table 4 also indicates that one nonurban cycle is sufficient to stabilize a vehicle that has been cold started. The soak time between a 1975 FTP and two repeats of the nonurban cycle is, therefore, not important if the second nonurban cycle is used for the fuel economy determination.

To facilitate the running of the nonurban cycle in conjunction with the standard EPA emission test, it was decided to routinely conduct the nonurban tests from stabilized or warmed-up vehicles. Although this way of conducting the test sacrifices knowledge of the warmup fuel economy characteristics of the vehicle on the nonurban cycle, it is an example of a tradeoff made because of facilities and manpower limits. Additionally, the authors feel that the warmed-up highway fuel economy value is of more interest to the vehicle owner.

CONVENTIONAL VERSUS ROTARY ENGINES - At the conclusion of the cycle development, arrangements were made to obtain nonurban cycle fuel economy data on a broad range of vehicle-engine combinations. The initial testing was designed to compare the fuel economy of conventional engine-powered vehicles to rotary engine-powered vehicles.

All three models of the three rotary-powered vehicles available in the United States were used in the evaluation. These three rotary vehicles were compared to five conventional engine-powered cars. The list of vehicles used and some of their characteristics are shown in Table 5. All the vehicles were 1974 models.

Table 6 compares the fuel economy results of the standard 1975 FTP (cold start) and the nonurban cycle on each of the cars from Table 5. The data shown in Table 6 indicate that the nonurban cycle fuel economy of all vehicles tested was significantly higher than the urban cycle economy, with the

Table 4 - Warmup Characteristics on the Nonurban Cycle

Type of Preconditioning	Fully Warmed-up Nonurban Fuel Economy, % Cycle 1	Cycle 2	Cycle 3	Cycle 4
1975 FTP, 1 h soak	98	101	100	--
12 h cold soak	89	102	101	100

Table 5 - Vehicle Characteristics

Vehicle	Engine Displacement	Transmission Type	Inertia Weight Class, lb
Mazda RX2	140 CID	M4	2750
Mazda RX3	140 CID	A3	2750
Mazda RX4	160 CID	M4	3000
AMC Gremlin	232 CID	A3	3000
Saab 99 EMS	121 CID	M4	2750
Chevrolet Vega	140 CID	M4	3000
Chevrolet Vega	140 CID	A3	3000
Ford Torino	351 CID	A3	4500

Table 6 - Conventional Versus Rotary Engined-Vehicles Urban and Nonurban Cycle Fuel Economy

Vehicle	Urban Fuel Economy, mpg	Nonurban Fuel Economy, mpg	Ratio of Nonurban to Urban
Mazda RX2	14.0	21.2	1.51
Mazda RX3	14.2	19.0	1.34
Mazda RX4	13.1	20.5	1.56
AMC Gremlin	18.5	27.2	1.47
Saab 99 EMS	21.4	30.6	1.43
Vega (manual)	18.3	30.4	1.43
Vega (automatic)	19.8	27.7	1.40
Ford Torino	13.2	20.1	1.52

ratio of nonurban fuel economy to urban fuel economy varying from 1.34:1 to 1.66:1. The average ratio for the rotary-powered cars was 1.47, compared to 1.50 for the conventional engine-powered cars. The rotary-powered cars, while demonstrating significantly lower fuel economy than conventional engine-powered cars of equivalent weight, did not show any significant difference in the percentage of improvement expected in nonurban operation over urban operation.

Table 7 shows additional data on conventional engine-powered vehicles which has been accumulated. No significant trends are apparent.

UNCONVENTIONAL ENGINES - Table 8 shows the results of a variety of unconventional powerplants that have been tested using both the 1975 FTP and the nonurban cycle. The increase in economy on the nonurban cycle compared to the urban cycle ranges from as little as 13% to as much as 126% for the vehicles tested.

Table 7 - Additional Conventional Engine Vehicles
Urban and Nonurban Fuel Economy

Vehicle	Inertia Weight Class, lb	Urban Fuel Economy, mpg	Nonurban Fuel Economy, mpg	Ratio of Nonurban to Urban
1970 Impala	4500	13.9	24.7	1.78
1971 Vega	2500	23.7	37.9	1.60
1962 Impala	4000	15.2	20.4	1.34
1963 Ford	4000	11.6	18.4	1.59
1975 certification subcompact	3000	18.5	27.9	1.51
1975 certification compact	3500	14.4	21.9	1.52
1975 intermediate	4500	13.4	18.8	1.31
1976 interim standard prototype	5000	10.9	15.8	1.45
1977 prototype (three-way catalyst)	2500	22.0	37.1	1.69

Table 8 - Unconventional Engine Vehicles
Urban and Nonurban Fuel Economy

Vehicle (Engine Type)	Inertia Weight, lb	Urban Fuel Economy, mpg	Nonurban Fuel Economy, mpg	Ratio of Nonurban to Urban
Mercedes 220D (diesel engine)	3500	24.4	32.4	1.33
Peugeot 504D (diesel engine)	3000	25.8	36.7	1.42
PROCO Capri (stratified charge engine)	2750	22.6	31.7	1.40
CVCC Honda (stratified charge engine)	2000	26.4	36.5	1.38
Suzuki (2-stroke with afterburner)	1750	17.2	28.0	1.63
J. Carter Steamer (Rankine cycle)	2750	14.9	16.8	1.13
PetroElectric (Wankel/electric hybrid)	4000	9.5	21.5	2.26

Diesel engine-powered vehicles, while exhibiting significantly better fuel economy than conventional vehicles, do not appear to have a significantly different ratio of nonurban to urban economy. This indicates that the nonurban cycle does not load the vehicle so highly that the diesel's part load advantage over the conventional engine is diminished.

The Rankine engine-powered vehicle exhibited a relatively poor fuel economy compared to conventional vehicles in urban driving and also had a low ratio of nonurban to urban fuel economy. The Rankine-powered vehicle, therefore, compares even less favorably in highway driving.

One example of a hybrid vehicle shows a 126% improvement in fuel economy comparing the highway cycle to the urban cycle. This particular car used a gasoline-powered Wankel engine/motor generator/battery power system.

Vehicles powered by the stratified charge Honda and PROCO engines do not appear to be significantly different from conventional engine-powered vehicles.

The vehicle incorporating a 2-stroke engine with an afterburner produced a conventional nonurban-urban fuel economy ratio, but the absolute fuel economy level in both the urban and highway cycles was extremely poor considering the vehicle's test weight.

CONCLUSIONS

1. As is the case with urban driving, nonurban driving can also be simulated using a chassis dynamometer.
2. Passenger cars with conventional engines typically exhibit fuel economy on the nonurban or "highway" cycle that is 50% greater than the fuel economy during urban driving as typified by the 1975 FTP.
3. The ratio of nonurban to urban fuel economy is about the same for conventional-engined vehicles and currently available rotary engine vehicles.
4. Emission control systems appear to have little effect on the ratio of nonurban to urban fuel economy for conventional engine-powered vehicles.
5. Vehicles with unconventional propulsion systems can exhibit significantly different ratios of nonurban to urban fuel economy.

REFERENCES

1. "Part II of the 1972 National Highway Needs Report," prepared by the U.S. Department of Transportation, House Document No. 92-266, Part II, April 1972.
2. "National Personal Transportation Study." Report No. 3, U.S. Department of Transportation, Federal Highway Administration, April 1972.

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VEHICLE-TO-VEHICLE EMISSION VARIABILITY

In its October 4, 1991 submission to EPA, Ethyl claims that the vehicle-to-vehicle HC emissions variability from the Explorer vehicle is high, and that the MMT additive is not the critical variable. We disagree with both statements. First, the variability in emission data seen on the clear-fueled Explorer vehicles at 55,000 miles from 0.15 gpm for vehicle #305 and 0.35 gpm for vehicle #307 is not unlike the variability seen from clear-fueled vehicles in Ethyl's fleet, nor is it unlike the variability seen from the fleet of thousands of 50,000-mile Ford-EPA certification vehicles. At the 50,000-mile test, Ethyl's clear-fueled Ford Escort demonstrated test variability from 0.13 gpm (vehicle E4) to 0.32 gpm (vehicle E2) (includes catalyst efficiency test data). Second, the larger variability in test results at 55,000 for MMT-fueled Ford vehicles from 0.17 gpm for vehicle #306 to 0.55 gpm for vehicle #304 are a result of the different rates of MMT contamination of the engines and emission control devices on these vehicles. Vehicle #304 was adversely affected more quickly than vehicle #306. However, the HC levels from these two vehicles after 100,000 miles with MMT were more in line. Vehicle #306 had an average HC level of 0.66 gpm and vehicle #304, 0.89 gpm at 100,000 miles. This variability is similar to that from some Ethyl test vehicles. The difference (delta) between these two Ford vehicles of 0.38 gpm HC at 55,000 miles is very similar to the difference Ethyl's Dodge test vehicles demonstrated. These Dodge test vehicles have a delta of 0.36 gpm between one test on vehicle D4 (0.55 gpm) and one test on vehicle D5 (0.91 gpm). As such, for Ethyl to question the representativeness of Ford test data based on test variability would also apply to its data. Again, these differences or variabilities are not uncommon to test data generated by Ford for other test programs which are orders of magnitude greater than the Ethyl test data.

The variability of Ethyl's emission test data within model types at 50,000 miles with MMT varied from a low of 0.02 gpm HC for Model I to as high as 0.36 gpm HC for Model D. For the clear-fueled models, the variability within model types ranged from 0.05 gpm HC for Model G to 0.27 gpm for Model F. From these data, Ethyl averaged together all the MMT results and compared it to all the clear results. It is not good engineering practice to average together data with 0.02 variability and data which has 0.36 variability. From these averages, Ethyl concludes that MMT causes an "increase in average HC emissions of between 0.01 to 0.018 gpm, depending upon how the data are interpreted." From the large variability within model types of up to 0.36 gpm HC with MMT fuel and up to 0.27 gpm HC with clear fuel, it is wrong to attempt to conclude the effect of MMT is 0.01 to 0.018 gpm. The wide variability observed does not allow for this conclusion. The effect of MMT could be much greater, as it could be masked by test variability.

FORD ANALYSIS OF ETHYL'S TEST DATA

Ford has analyzed the data from Ethyl's 48-vehicle test fleet and reached different conclusions than Ethyl. As a starting point, we eliminated test data after fuel injector replacement (Model Types D, E, F, T, H and I). The reasons for removing these data are three-fold: (1) fuel injector replacement is not scheduled maintenance, it is not recommended by the manufacturers; (2) after the replacement of fuel injectors on Model Types D, F, T and H, the HC emission trended back down or leveled off at 50,000 miles, which is not normal deterioration (it indicates the replacement biased the data); and (3) the Ford fuel injector test results on Explorer #306 and #305 (contained in prior Attachment) demonstrates the fuel injector replacement improves emissions levels after 100,000 miles. For Model Types G and C, we calculated intercepts and deterioration factors (DFs) through 75,000 miles, as these vehicles did not undergo fuel injector replacement.

Attached are the Ford calculations for HC and NOx at 4K, 50K and 100K, and the 50K and 100K deterioration factors. At the 50K point, the average HC value for clear fuel is 0.362 gpm, and that for MMT fuel is 0.389 gpm. MMT has adversely affected HC emissions by 0.027 gpm which is twice the average value claimed by Ethyl of 0.014 gpm. MMT has caused an increase in HC levels of more than 10% of what the new HC standard of 0.25 gpm will be.

PERCENT DIFFERENCES BETWEEN HT3 AND EEE

ENGINE FAMILY	FUEL TYPE	HC SLOPE	HC Y-INT	HC EMISSIONS 4K	50K	100K	DF(50K)	DF(100K)	NOx SLOPE	NOx Y-INT	NOx EMISSIONS 4K	50K	100K	DF(50K)	DF(100K)
E	HT3	9.22E-07	0.1693	0.1730	0.2154	0.2615	1.2455	1.5124	4.39E-06	0.2311	0.2487	0.4508	0.6706	1.8136	2.6979
	EEE	1.89E-06	0.1197	0.1273	0.2140	0.3082	1.6798	2.4187	3.39E-06	0.2729	0.2865	0.4422	0.6115	1.5548	2.1579
	% DIFF.=	-51.1%	41.4%	35.9%	0.7%	-15.2%	-25.9%	-37.5%	29.8%	-15.3%	-13.2%	2.0%	9.7%	16.6%	25.0%
F	HT3	8.86E-06	0.2583	0.2937	0.7012	1.1442	2.3960	3.9135	1.33E-06	0.6357	0.6410	0.7021	0.7686	1.1081	1.2257
	EEE	1.03E-05	0.2208	0.2619	0.7345	1.2482	2.8324	4.8241	8.38E-06	0.6358	0.6693	1.0549	1.4740	1.6220	2.2981
	% DIFF.=	-13.8%	16.9%	12.1%	-4.5%	-8.3%	-15.4%	-18.9%	-84.1%	0.0%	-4.2%	-33.4%	-47.9%	-31.7%	-46.7%
G	HT3	6.89E-07	0.1401	0.1428	0.1745	0.2089	1.2206	1.460453	1.13E-06	0.3253	0.3299	0.3819	0.4385	1.1637	1.3416
	EEE	4.72E-07	0.1172	0.1191	0.1408	0.1644	1.1833	1.382595	1.88E-06	0.3162	0.3237	0.4101	0.5041	1.2754	1.5747
	% DIFF.=	46.0%	19.5%	19.9%	23.9%	27.1%	3.2%	5.6%	-39.8%	2.9%	1.9%	-6.9%	-13.0%	-8.8%	-14.8%
H	HT3	3.03E-06	0.1914	0.2036	0.3430	0.4945	1.6823	2.423947	-2.94E-06	0.5224	0.5106	0.3752	0.2281	0.7805	0.5420
	EEE	3.01E-06	0.1944	0.2064	0.3449	0.4954	1.6797	2.418543	1.82E-06	0.3436	0.3509	0.4344	0.5253	1.4337	1.9051
	% DIFF.=	0.7%	-1.5%	-1.4%	-0.6%	-0.2%	0.2%	0.2%	-262.0%	52.0%	45.5%	-13.6%	-56.6%	-45.6%	-71.6%

PERCENT DIFFERENCES BETWEEN HT3 AND EEE

ENGINE FAMILY	FUEL TYPE	HC SLOPE	HC Y-INT	HC EMISSIONS 4K	50K	100K	DF(50K)	DF(100K)	NOx SLOPE	NOx Y-INT	NOx EMISSIONS 4K	50K	100K	DF(50K)	DF(100K)
D	HT3	1.03E-05	0.2721	0.3134	0.7891	1.3061	2.5332	4.199771	-3.8E-06	0.5662	0.5510	0.3762	0.1862	0.6883	0.3495
	EEE	7.82E-06	0.2697	0.3010	0.6605	1.0512	2.1932	3.4902	-3.9E-06	0.5364	0.5208	0.3414	0.1464	0.6550	0.2799
	% DIFF	32.31%	0.89%	4.13%	19.47%	24.24%	15.50%	20.33%	-2.56%	5.54%	5.79%	10.17%	27.16%	5.09%	[illegible]
C	HT3	4.78E-07	0.2004	0.2023	0.2243	0.2482	1.1069	1.2231	2.12E-06	0.2198	0.2283	0.3258	0.4318	1.4270	1.8912
	EEE	5.28E-07	0.1598	0.1619	0.1862	0.2126	1.1563	1.3262	5.69E-06	0.2089	0.2316	0.4934	0.7779	2.1231	3.3439
	% DIFF	-9.47%	25.43%	[illegible]	20.47%	16.75%	-4.27%	-7.78%	-62.74%	5.26%	-1.42%	-33.95%	-44.48%	-32.79%	[illegible]
I	HT3	3.39E-07	0.1843	0.1856	0.2012	0.2181	1.0971	1.2027	5.09E-07	0.3625	0.3645	0.3879	0.4134	1.0809	1.1688
	EEE	1.92E-07	0.1790	0.1797	0.1886	0.1982	1.0504	1.1053	9.05E-07	0.3912	0.3949	0.4365	0.4818	1.1709	1.3567
	% DIFF	76.17%	2.96%	3.28%	6.70%	10.07%	4.44%	8.81%	-43.78%	-7.35%	-7.69%	-11.13%	-14.20%	-7.69%	-13.85%
T	HT3	4.47E-06	0.2382	0.2561	0.4616	0.6849	1.8052	2.6804	2.75E-06	0.4456	0.4566	0.5832	0.7208	1.2765	1.5771
	EEE	4.69E-06	0.1918	0.2105	0.4263	0.6608	2.0268	3.1429	-2.4E-06	0.8186	0.8089	0.6974	0.5763	0.9153	0.8232
	% DIFF	-4.76%	24.21%	21.63%	8.27%	3.65%	-10.93%	-14.71%	-213.59%	-45.57%	-43.56%	-16.38%	25.08%	39.47%	91.58%

MMT.XLS

VEH	FUEL	HC	HC	HC EMISSIONS					NOx	NOx	NOx EMISSIONS				
#	TYPE	SLOPE	Y-INT	4K	50K	100K	DF(50K)	DF(100K)	SLOPE	INT	4K	50K	100K	DF(50K)	DF(100K)
D4	HT3	1.16E-05	0.2519	0.2983	0.8319	1.4119	2.7889	4.7333	-6.5E-06	0.6066	0.5806	0.2816	-0.0434	0.4850	-0.0748
D5	HT3	1.02E-05	0.2552	0.2960	0.7652	1.2752	2.5852	4.3082	-2.6E-06	0.5540	0.5436	0.4240	0.2940	0.7800	0.5408
D6	HT3	9.22E-06	0.3092	0.3460	0.7702	1.2312	2.2257	3.5579	-2.3E-06	0.5380	0.5288	0.4230	0.3080	0.7999	0.5824
	AVE:	1.03E-05	0.2721	0.3134	0.7891	1.3061	2.5332	4.1998	-3.8E-06	0.5662	0.5510	0.3762	0.1862	0.6883	0.3493
D1	EEE	7.33E-06	0.2643	0.2936	0.6308	0.9973	2.1484	3.3968	-4E-06	0.5660	0.5500	0.3660	0.1660	0.6655	0.3019
D2	EEE	8.3E-06	0.2752	0.3084	0.6902	1.1052	2.2380	3.5836	-3.8E-06	0.5068	0.4916	0.3168	0.1268	0.6445	0.2580
D3	EEE	VEHICLE DID NOT COMPLETE TESTING.													
	AVE:	7.82E-06	0.2697	0.3010	0.6605	1.0512	2.1932	3.4902	-3.9E-06	0.5364	0.5208	0.3414	0.1464	0.6550	0.2799
C2	HT3	4.27E-07	0.1940	0.1957	0.2153	0.2367	1.1004	1.2095	2.94E-06	0.2122	0.2240	0.3592	0.5062	1.6038	2.2601
C3	HT3	8.11E-07	0.2104	0.2136	0.2510	0.2915	1.1746	1.3644	2.09E-06	0.2321	0.2405	0.3366	0.4411	1.3998	1.8343
C6	HT3	1.96E-07	0.1967	0.1975	0.2065	0.2163	1.0456	1.0953	1.33E-06	0.2152	0.2205	0.2817	0.3482	1.2775	1.5790
	AVE:	4.78E-07	0.2004	0.2023	0.2243	0.2482	1.1069	1.2231	2.12E-06	0.2198	0.2283	0.3258	0.4318	1.4270	1.8912
C1	EEE	2.14E-07	0.1763	0.1772	0.1870	0.1977	1.0556	1.1160	6.05E-06	0.1897	0.2139	0.4922	0.7947	2.3011	3.7154
C4	EEE	1.7E-07	0.1559	0.1565	0.1644	0.1729	1.0500	1.1043	7.01E-06	0.2457	0.2738	0.5962	0.9467	2.1779	3.4582
C5	EEE	1.2E-06	0.1471	0.1519	0.2071	0.2671	1.3634	1.7584	4.01E-06	0.1911	0.2072	0.3916	0.5921	1.8904	2.8581
	AVE:	5.28E-07	0.1598	0.1619	0.1862	0.2126	1.1563	1.3262	5.69E-06	0.2089	0.2316	0.4934	0.7779	2.1231	3.3439
I2	HT3	-2.1E-07	0.2183	0.2174	0.2078	0.1973	0.9556	0.9073	-1.2E-06	0.4374	0.4326	0.3774	0.3174	0.8724	0.7337
I4	HT3	8.04E-07	0.1614	0.1646	0.2016	0.2418	1.2247	1.4690	8.27E-07	0.3017	0.3050	0.3431	0.3844	1.1247	1.2603
I6	HT3	4.22E-07	0.1731	0.1748	0.1942	0.2153	1.1110	1.2317	1.9E-06	0.3483	0.3559	0.4433	0.5383	1.2456	1.5125
	AVE:	3.39E-07	0.1843	0.1856	0.2012	0.2181	1.0971	1.2027	5.09E-07	0.3625	0.3645	0.3879	0.4134	1.0809	1.1688
I1	EEE	1.91E-07	0.1890	0.1897	0.1985	0.2081	1.0463	1.0966	1.56E-07	0.3824	0.3830	0.3902	0.3980	1.0187	1.0391
I3	EEE	3.17E-08	0.1814	0.1816	0.1830	0.1846	1.0080	1.0168	3.96E-06	0.2776	0.2935	0.4756	0.6736	1.6208	2.2955
I5	EEE	3.54E-07	0.1664	0.1679	0.1841	0.2018	1.0970	1.2025	-1.4E-06	0.5138	0.5082	0.4438	0.3738	0.8733	0.7355
	AVE:	1.92E-07	0.1790	0.1797	0.1886	0.1982	1.0504	1.1053	9.05E-07	0.3912	0.3949	0.4365	0.4818	1.1709	1.3567
T1	HT3	5.67E-06	0.2269	0.2496	0.5104	0.7939	2.0450	3.1808	3.67E-06	0.4728	0.4874	0.6563	0.8398	1.3463	1.7228
T4	HT3	4.14E-06	0.2441	0.2607	0.4511	0.6581	1.7305	2.5245	3.83E-06	0.4194	0.4347	0.6109	0.8024	1.4053	1.8458
T5	HT3	3.59E-06	0.2436	0.2580	0.4231	0.6026	1.6401	2.3359	7.58E-07	0.4445	0.4476	0.4824	0.5203	1.0779	1.1626
	AVE:	4.47E-06	0.2382	0.2561	0.4616	0.6849	1.8052	2.6804	2.75E-06	0.4456	0.4566	0.5832	0.7208	1.2765	1.5771
T2	EEE	4.51E-06	0.1866	0.2047	0.4121	0.6376	2.0136	3.1153	-4.3E-07	0.7453	0.7436	0.7238	0.7023	0.9734	0.9445
T3	EEE	5.43E-06	0.1872	0.2090	0.4587	0.7302	2.1953	3.4946	2.56E-06	0.6254	0.6357	0.7534	0.8814	1.1853	1.3866
T6	EEE	4.13E-06	0.2015	0.2180	0.4080	0.6145	1.8715	2.8187	-9.4E-06	1.0851	1.0475	0.6151	0.1451	0.5872	0.1385
	AVE:	4.69E-06	0.1918	0.2105	0.4263	0.6608	2.0268	3.1429	-2.4E-06	0.8186	0.8089	0.6974	0.5763	0.9153	0.8232

ORIGINAL ETHYL MMT DATA SUMMARY

VEH	FUEL	HC	HC	HC EMISSIONS					NOx	NOx	NOx EMISSIONS				
#	TYPE	SLOPE	Y-INT	4K	50K	100K	DF(50K)	DF(100K)	SLOPE	Y-INT	4K	50K	100K	DF(50K)	DF(100K)
F1	HT3	8.06E-06	0.2772	0.3095	0.6801	1.0829	2.1976	3.4994	-1.34E-06	0.7149	0.7095	0.6477	0.5805	0.9128	0.8181
F2	HT3	8.92E-06	0.2617	0.2974	0.7076	1.1536	2.3798	3.8796	4.79E-06	0.5741	0.5933	0.8135	1.0528	1.3711	1.7745
F3	HT3	9.60E-06	0.2359	0.2743	0.7160	1.1962	2.6107	4.3614	5.45E-07	0.6180	0.6202	0.6452	0.6725	1.0404	1.0844
	AVG:	8.86E-06	0.2583	0.2937	0.7012	1.1442	2.3960	3.9135	1.33E-06	0.6357	0.6410	0.7021	0.7686	1.1081	1.2257
F4	EEE	9.76E-06	0.1927	0.2318	0.6810	1.1692	2.9378	5.0440	1.58E-05	0.5087	0.5720	1.2998	2.0908	2.2723	3.6552
F5	EEE	9.07E-06	0.2632	0.2995	0.7169	1.1705	2.3938	3.9089	5.78E-06	0.7155	0.7386	1.0046	1.2937	1.3601	1.7514
F6	EEE	1.20E-05	0.2066	0.2545	0.8057	1.4048	3.1656	5.5194	3.54E-06	0.6832	0.6974	0.8604	1.0376	1.2337	1.4878
	AVG:	1.03E-05	0.2208	0.2619	0.7345	1.2482	2.8324	4.8241	8.38E-06	0.6358	0.6693	1.0549	1.4740	1.6220	2.2981
G3	HT3	8.29E-07	0.1526	0.1559	0.1940	0.2355	1.2447	1.5107	5.67E-07	0.3481	0.3503	0.3764	0.4047	1.0744	1.1553
G5	HT3	4.88E-07	0.1334	0.1354	0.1578	0.1822	1.1658	1.3459	1.68E-06	0.2858	0.2925	0.3698	0.4539	1.2644	1.5518
G6	HT3	7.50E-07	0.1341	0.1371	0.1716	0.2091	1.2514	1.5247	1.15E-06	0.3422	0.3468	0.3995	0.4569	1.1522	1.3177
	AVG:	6.89E-07	0.1401	0.1428	0.1745	0.2089	1.2206	1.4605	1.13E-06	0.3253	0.3299	0.3819	0.4385	1.1637	1.3416
G1	EEE	4.69E-07	0.1165	0.1184	0.1399	0.1634	1.1823	1.3805	1.33E-06	0.3159	0.3212	0.3822	0.4484	1.1898	1.3960
G2	EEE	5.70E-07	0.1128	0.1151	0.1413	0.1698	1.2277	1.4751	3.14E-06	0.2868	0.2994	0.4439	0.6010	1.4827	2.0073
G4	EEE	3.77E-07	0.1223	0.1238	0.1412	0.1600	1.1400	1.2921	1.17E-06	0.3458	0.3505	0.4043	0.4629	1.1537	1.3208
	AVG:	4.72E-07	0.1172	0.1191	0.1408	0.1644	1.1833	1.3826	1.88E-06	0.3162	0.3237	0.4101	0.5041	1.2754	1.5747
E1	HT3	8.91E-07	0.1720	0.1756	0.2165	0.2611	1.2333	1.4869	3.82E-06	0.2282	0.2434	0.4192	0.6102	1.7219	2.5066
E5	HT3	9.84E-07	0.1626	0.1666	0.2118	0.2610	1.2718	1.5672	4.15E-06	0.2401	0.2567	0.4478	0.6555	1.7443	2.5534
E6	HT3	8.90E-07	0.1733	0.1769	0.2178	0.2623	1.2315	1.4831	5.21E-06	0.2251	0.2459	0.4855	0.7459	1.9745	3.0337
	AVG:	9.22E-07	0.1693	0.1730	0.2154	0.2615	1.2455	1.5124	4.39E-06	0.2311	0.2487	0.4508	0.6706	1.8136	2.6979
E2	EEE	2.75E-06	0.1237	0.1347	0.2614	0.3990	1.9403	2.9623	4.42E-06	0.2580	0.2757	0.4791	0.7002	1.7379	2.5400
E3	EEE	1.87E-06	0.1097	0.1172	0.2031	0.2964	1.7327	2.5292	4.09E-06	0.2601	0.2765	0.4645	0.6689	1.6802	2.4196
E4	EEE	1.03E-06	0.1258	0.1299	0.1775	0.2293	1.3664	1.7647	1.65E-06	0.3007	0.3073	0.3830	0.4653	1.2463	1.5141
	AVG:	1.89E-06	0.1197	0.1273	0.2140	0.3082	1.6798	2.4187	3.39E-06	0.2729	0.2865	0.4422	0.6115	1.5548	2.1579
H3	HT3	3.16E-06	0.1750	0.1876	0.3332	0.4914	1.7756	2.6186	-3.03E-06	0.5646	0.5525	0.4132	0.2619	0.7480	0.4741
H4	HT3	1.72E-06	0.1971	0.2039	0.2829	0.3687	1.3871	1.8078	-5.61E-06	0.7091	0.6867	0.4288	0.1484	0.6244	0.2161
H6	HT3	4.21E-06	0.2023	0.2191	0.4129	0.6235	1.8842	2.8454	-1.96E-07	0.2936	0.2928	0.2838	0.2740	0.9692	0.9357
	AVG:	3.03E-06	0.1914	0.2036	0.3430	0.4945	1.6823	2.4239	-2.94E-06	0.5224	0.5106	0.3752	0.2281	0.7805	0.5420
H1	EEE	2.27E-06	0.2136	0.2227	0.3273	0.4410	1.4697	1.9802	4.95E-06	0.2047	0.2245	0.4523	0.6999	2.0147	3.1177
H2	EEE	4.02E-06	0.1806	0.1967	0.3815	0.5824	1.9397	2.9610	2.78E-06	0.2585	0.2696	0.3974	0.5364	1.4741	1.9895
H5	EEE	2.74E-06	0.1890	0.2000	0.3259	0.4628	1.6298	2.3144	-2.28E-06	0.5676	0.5585	0.4536	0.3396	0.8122	0.6080
	AVG:	3.01E-06	0.1944	0.2064	0.3449	0.4954	1.6797	2.4185	1.82E-06	0.3436	0.3509	0.4344	0.5253	1.4337	1.9051

PARTICULATE EMISSION RESULTS

Attached are additional particulate emission data from the Ford Escort and Explorer test vehicles. these data were collected through the 105,000-mile point and should be considered an addendum to the Ford report titled "Particulate Emissions from Current Model Vehicles Using Gasoline with Methylcyclopenladienyl Manganese Tricarbonyl", which was supplied to the Air Docket and Ms. Mary T. Smith in Ford's communication dated September 4, 1991.

This test data shows that the mass of particulates is higher on MMT-fueled vehicles than clear-fueled vehicles, and the amount of particulates increases with mileage.

APPENDIX

Particulate Emissions from Current Model Vehicles Using Gasoline with Methylcyclopentadienyl Manganese Tricarbonyl

R. H. Hammerle, T. J. Korniski, J. E. Weir,
E. Chladek, C. A. Gierczak and R. G. Hurley

Research Staff
Ford Motor Company
Dearborn, Michigan 48121

Updated Tables
October 29, 1991

Table 1

Particulate and Manganese Emissions from Explorers

Vehicle Number	Odometer (Miles)	Site 1 PM (mg/mi)	Site 2 PM (mg/mi)	Site 3 PM (mg/mi)	Site 4 PM (mg/mi)	Site 3 Mn (μg/mi)	Site 4 Mn (μg/mi)	Fraction of Mn Emitted
304	55,105[a]	1.49[d] ±1.15	3.09[f] ±0.27			n.a.	135[f]	7.9%
	55,182[a]	7.25[d] ±0.74	7.70[f] ±0.33			116[d]	115[f]	6.8%
	105,033[a]	4.87[d] ±0.37	3.69[f] ±0.74	3.81[d] ±0.05	3.27[f] ±0.03	783[d]	634[f]	41.7%
	105,110[a]	5.35[e] ±0.63	3.58[f] ±0.96	3.36[d] ±0.07	3.12[f] ±0.05	315[d]	296[f]	18.0%
307	55,158[a]	3.24[d] ±0.93	4.63[f] ±0.32			4[d]	4[f]	
	55,226[a]	3.93[d] ±0.62	3.62[f] ±0.31			6[d]	4[f]	
	105,099[a]	1.05[d] ±1.42	1.15[f] ±0.37	1.97[e] ±0.07	1.68[f] ±0.07	4[e]	2[f]	
	105,175[a]	0.71[d] ±0.62	1.01[f] ±0.25	1.24[d] ±0.05	1.19[f] ±0.04	2[d]	1[f]	
	105,253[b]	4.83[d] ±1.37	5.65[f] ±0.95	6.22[d] ±0.32	3.07[f] ±0.25	4[d]	2[f]	

a Average of six three-phase tests
b One three-phase UDDS test
c TX40 filter
d Zefluor filter 0.5 u pore size
e Zefluor filter 1.0 u pore size
f PTFE filter 0.2 u pore size
g PTFE filter 0.45u pore size
h T60A20 filter

Table 2

Particulate and Manganese Emissions from Explorers								
Vehicle Number	**Odometer (Miles)**	**Site 1 PM (mg/mi)**	**Site 2 PM (mg/mi)**	**Site 3 PM (mg/mi)**	**Site 4 PM (mg/mi)**	**Site 3 Mn (μg/mi)**	**Site 4 Mn (μg/mi)**	**Fraction of Mn Emitted**
305	5,123[a]	n.a.	0.08[c] ±0.42			4[e]	n.a.	
	20,272[a]	2.31[d] ±0.68	1.28[e] ±0.92			6[d]	3[f]	
	55,173[a]	n.a.	2.13[f] ±0.49			2[d]	3[f]	
	55,250[a]	2.08[d] ±1.03	2.18[f] ±0.35			2[d]	1[f]	
	55,326[a]	1.39[d] ±2.09	2.50[f] ±0.31			3[d]	1[f]	
	85,177[a]	1.56[d] ±0.63	1.80[f] ±0.34	1.68[d] ±0.10	1.51[f] ±0.05	3[d]	2[f]	
	85,258[a]	2.95[d] ±0.29	2.11[f] ±0.32	2.14[d] ±0.04	1.89[f] ±0.07	3[d]	2[f]	
	105,096[a]	2.27[d] ±1.43	0.62[f] ±0.51	1.47[e] ±0.10	1.37[f] ±0.11	4[e]	2[f]	
	105,172[a]	1.93[d] ±0.99	2.08[f] ±0.26	2.58[e] ±0.06	2.60[f] ±0.06	2[e]	5[f]	
	105,249[b]	4.95[d] ±2.60	4.81[f] ±1.30	6.63[e] ±0.86	5.95[f] ±0.49	8[e]	9[f]	

a Average of six three-phase tests
b One three-phase UDDS test
c TX40 filter
d Zefluor filter 0.5 u pore size
e Zefluor filter 1.0 u pore size
f PTFE filter 0.2 u pore size
g PTFE filter 0.45u pore size
h T60A20 filter

Table 3

Particulate and Manganese Emissions from Explorers								
Vehicle Number	**Odometer (Miles)**	**Site 1 PM (mg/mi)**	**Site 2 PM (mg/mi)**	**Site 3 PM (mg/mi)**	**Site 4 PM (mg/mi)**	**Site 3 Mn (µg/mi)**	**Site 4 Mn (µg/mi)**	**Fraction of Mn Emitted**
306	5,141[a]	n.a.	1.70[c] ±0.32			173[e]	181[e]	10.4%
	20,213[a]	3.59[d] ±1.55	2.82[f] ±0.44			186[f]	158[h]	10.1%
	20,290[a]	3.73[d] ±0.30	2.71[e] ±0.62			122[d]	132[f]	7.5%
	55,273[a]	3.97[d] ±0.46	1.92[f] ±0.40			325[d]	289[f]	18.1%
	55,349[a]	5.79[d] ±0.44	4.62[f] ±0.58			227[d]	232[f]	13.5%
	85,078[a]	4.41[d] ±0.61	3.10[f] ±0.41	0.95[d] ±0.14	2.50[f] ±0.10	259[d]	265[f]	15.4%
	85,155[a]	3.11[d] ±0.68	2.45[f] ±0.47	2.34[d] ±0.06	2.19[f] ±0.13	311[d]	289[f]	17.6%
	105,172[a]	4.27[d] ±0.27	4.51[f] ±0.24	3.02[d] ±0.04	3.18[f] ±0.05	310[d]	290[f]	17.6%
	105,248[a]	3.55[d] ±0.87	2.84[f] ±0.25	2.14[d] ±0.06	2.25[f] ±0.06	194[d]	183[f]	11.1%
	105,325[b]	8.61[d] ±1.37	13.23[f] ±0.96	5.28[d] ±0.24	4.76[f] ±0.20	301[d]	283[f]	17.2%

a Average of six three-phase tests
b One three-phase UDDS test
c TX40 filter
d Zefluor filter 0.5 u pore size
e Zefluor filter 1.0 u pore size
f PTFE filter 0.2 u pore size
g PTFE filter 0.45u pore size
h T60A20 filter

Table 4

Particulate and Manganese Emissions from Escorts								
Vehicle Number	Odometer (Miles)	Site 1 PM (mg/mi)	Site 2 PM (mg/mi)	Site 3 PM (mg/mi)	Site 4 PM (mg/mi)	Site 3 Mn (μg/mi)	Site 4 Mn (μg/mi)	Fraction of Mn Emitted
315	5,108[a]	0.11[f] ±0.31	0.83[d] ±0.38			1[f]	0[d]	
	20,029[a]	n.a.	n.a.			4[d]	3[f]	
	20,187[a]	2.75[e] ±0.27	2.30[f] ±0.47			10[d]	8[f]	
	20,264[b]	3.92[e] ±1.97	2.83[f] ±1.50			10[d]	10[f]	
	55,100[a]	1.71[d] ±1.32	2.66[f] ±0.33			3[d]	2[f]	
	55,177[a]	1.52[d] ±0.44	1.41[f] ±0.43			1[d]	2[f]	
	85,018[a]	0.83[e] ±1.17	2.21[f] ±0.39	2.15[d] ±0.06	2.11[f] ±0.02	2[d]	2[f]	
	85,095[a]	3.21[e] ±0.81	1.04[f] ±0.56	2.25[d] ±0.06	2.19[f] ±0.05	2[d]	3[f]	
	105,094[a]	2.15[d] ±0.36	2.54[f] ±0.70	1.79[d] ±0.08	1.74[f] ±0.05	5[d]	2[f]	
	105,172[b]	3.85[d] ±1.19	-5.78[f] ±3.05	4.58[d] ±0.30	3.08[f] ±0.29	10[d]	3[f]	
	105,193[a]	2.09[d] ±0.30	0.60[f] ±0.55	2.00[d] ±0.04	1.87[f] ±0.06	4[d]	2[f]	

a Average of six three-phase tests
b One three-phase UDDS test
b1 One highway fuel economy test
c TX40 filter
d Zefluor filter 0.5 u pore size
e Zefluor filter 1.0 u pore size
f PTFE filter 0.2 u pore size
g PTFE filter 0.45u pore size
h T60A20 filter

Table 5

Particulate and Manganese Emissions from Escorts								
Vehicle Number	Odometer (Miles)	Site 1 PM (mg/mi)	Site 2 PM (mg/mi)	Site 3 PM (mg/mi)	Site 4 PM (mg/mi)	Site 3 Mn (µg/mi)	Site 4 Mn (µg/mi)	Fraction of Mn Emitted
316	5,113[a]	0.78[f] ±0.34	2.93[d] ±0.33			11[g]	10[d]	1.1%
	20,025[a]	1.77[d] ±0.30	1.72[f] ±0.33			123[d]	119[f]	12.1%
	20,103[b]	3.00[d] ±1.35	4.89[f] ±1.20			148[d]	133[f]	14.1%
	20,115[b1]	-0.13[d] ±1.17	3.17[f] ±1.51			31[d]	29[f]	3.0%
	20,252[a]	2.83[e] ±0.47	1.91[f] ±0.23			191[d]	173[f]	18.2%
	20,328[b]	3.12[e] ±2.02	2.60[f] ±1.27			242[d]	243[f]	24.3%
	55,100[a]	4.10[d] ±0.45	4.80[f] ±0.39			448[d]	458[f]	45.3%
	55,177[a]	3.35[d] ±0.43	4.59[g] ±0.38			418[d]	415[f]	41.7%
	85,034[a]	1.48[e] ±2.46	2.57[f] ±0.33	2.61[d] ±0.06	2.50[f] ±0.04	72[d]	75[f]	7.4%
	85,112[a]	0.05[e] ±2.34	1.12[f] ±1.04	2.17[d] ±0.06	2.13[f] ±0.09	78[d]	107[f]	9.3%
	105,016[b]	7.49[d] ±1.17	13.47[f] ±0.97	4.02[d] ±0.35	4.34[f] ±0.20	150[d]	146[f]	14.8%
	105,118[a]	2.24[d] ±0.26	1.15[f] ±0.48	1.77[d] ±0.06	1.61[f] ±0.03	53[d]	76[f]	6.5%
	105,195[a]	2.25[d] ±0.21	2.05[f] ±0.29	1.81[d] ±0.04	1.70[f] ±0.03	64[d]	61[f]	6.3%

a Average of six three-phase tests
b One three-phase UDDS test
b1 One highway fuel economy test
c TX40 filter
d Zefluor filter 0.5 u pore size
e Zefluor filter 1.0 u pore size
f PTFE filter 0.2 u pore size
g PTFE filter 0.45u pore size
h T60A20 filter

Table 6

Particulate and Manganese Emissions from Escorts								
Vehicle Number	Odometer (Miles)	Site 1 PM (mg/mi)	Site 2 PM (mg/mi)	Site 3 PM (mg/mi)	Site 4 PM (mg/mi)	Site 3 Mn (μg/mi)	Site 4 Mn (μg/mi)	Fraction of Mn Emitted
317	55,114[a]	1.60[d] ±0.29	0.94[f] ±0.36	n.a.	n.a.	2[d]	4[f]	
	55,191[a]	3.37[d] ±0.77	1.88[f] ±0.29	n.a.	n.a.	2[d]	n.a.	
	105,093[b]	3.95[d] ±1.88	4.29[f] ±1.82	3.98[d] ±0.28	3.67[f] ±0.63	5[d]	4[f]	
	105,117[a]	1.71[d] ±0.35	2.04[f] ±0.56	1.59[d] ±0.07	1.70[f] ±0.08	2[d]	2[f]	
	105,195[a]	0.94[d] ±0.25	0.86[f] ±0.31	1.54[d] ±0.05	1.46[f] ±0.05	2[d]	2[f]	
318	55,015[a]	2.40[d] ±1.36	2.02[f] ±0.35	2.45[d] ±0.10	1.94[f] ±0.04	165[d]	144[f]	15.5%
	55,093[a]	0.25[d] ±0.93	2.18[f] ±0.27	2.15[d] ±0.04	2.04[f] ±0.04	106[d]	108[f]	10.7%
	105,018[a]	3.78[d] ±0.30	2.50[f] ±0.65	3.59[d] ±0.08	3.25[f] ±0.07	157[d]	125[f]	14.1%
	105,096[a]	1.96[d] ±0.19	2.50[f] ±0.72	2.35[d] ±0.05	2.30[f] ±0.06	108[d]	104[f]	10.6%
	105,173[b]	10.06[d] ±1.22	7.22[f] ±3.08	6.11[d] ±0.30	4.69[f] ±0.18	223[d]	204[f]	21.4%

a Average of six three-phase tests
b One three-phase UDDS test
b1 One highway fuel economy test
c TX40 filter
d Zefluor filter 0.5 u pore size
e Zefluor filter 1.0 u pore size
f PTFE filter 0.2 u pore size
g PTFE filter 0.45u pore size
h T60A20 filter

Table 7

Oil Analyses from Explorers							
Vehicle Number	Odometer (miles)	Mn Found (ppm)	As % Mn Expected (%)	Fe Found (ppm)	Cu Found (ppm)	Pb Found (ppm)	Si Found (ppm)
305	12,748	0		17	17	19	17
	20,425	0		17	14	16	15
	27,621	10		12	26	16	7
	35,167	5		14	21	20	11
	42,482	1		14	54	20	7
	49,792	1		12	45	22	9
	57,244	1		17	58	23	6
	64,785	0		14	68	20	8
	72,327	1		11	47	17	8
	79,914	0		12	28	21	10
	95,111	0		10	18	21	9
	102,830	0		12	69	11	7
	Average	2		14	39	19	10
306	12,470	158	5.5%	14	18	17	13
	20,565	270	8.3%	20	15	18	14
	27,585	257	9.1%	17	59	12	7
	35,184	218	7.2%	16	18	14	8
	42,485	194	6.6%	15	46	16	6
	49,950	320	10.7%	27	23	26	10
	57,169	252	8.7%	45	19	25	19
	64,847	219	7.1%	32	18	23	13
	72,388	203	6.7%	26	13	19	14
	79,986	236	7.7%	24	14	22	14
	87,411	163	5.5%	30	78	20	12
	95,123	264	8.5%	37	30	22	15
	102,602	208	6.9%	20	46	16	10
	Average	228	7.6%	25	31	19	12

Table 8

Oil Analyses from Explorers							
Vehicle Number	Odometer (miles)	Mn Found (ppm)	As % Mn Expected (%)	Fe Found (ppm)	Cu Found (ppm)	Pb Found (ppm)	Si Found (ppm)
304	15,651	191	5.8%	17	18	17	26
	22,184	221	8.4%	20	15	16	31
	30,130	235	7.4%	16	59	14	16
	37,400	325	11.1%	21	29	22	14
	45,015	214	7.0%	14	47	19	10
	52,441	276	9.3%	17	27	25	11
	59,988	238	7.9%	15	74	24	9
	67,231	224	7.7%	16	55	22	11
	74,753	235	7.8%	16	69	22	12
	82,291	231	7.6%	15	65	20	13
	90,005	191	6.2%	14	58	18	11
	97,794	258	8.3%	14	28	22	11
	105,367	281	9.2%	17	14	26	10
	Average	240	8.0%	16	43	21	14
307	15,811	1		21	30	21	36
	22,218	2		24	25	21	36
	29,957	2		12	23	19	17
	37,643	2		14	20	24	15
	45,230	1		13	18	21	12
	52,406	2		16	21	25	16
	60,330	1		16	52	27	14
	67,419	0		12	70	24	12
	74,920	0		11	64	20	11
	82,626	0		15	26	24	13
	89,893	0		12	46	16	13
	97,596	0		15	24	21	13
	105,448	0		18	14	16	10
	Average	1		15	33	21	17

Table 9

Oil Analyses from Escorts							
Vehicle Number	Odometer (miles)	Mn Found (ppm)	As % Mn Expected (%)	Fe Found (ppm)	Cu Found (ppm)	Pb Found (ppm)	Si Found (ppm)
315	12,236	4		26	32	30	64
	20,337	4.		19	24	30	35
	27,526	1		15	19	26	20
	42,309	1		12	21	22	13
	49,878	2		14	29	31	13
	57,473	1		14	26	30	19
	64,678	0		12	21	25	15
	72,575	0		11	21	33	14
	79,944	2		22	20	30	14
	87,550	6		13	17	29	12
	102,403	0		15	23	17	17
	Average	2		16	23	28	21
316	12,241	126	6.4%	26	25	17	52
	20,401	196	8.5%	38	19	19	33
	27,628	177	8.6%	24	21	20	19
	34,828	197	9.6%	18	18	21	15
	42,638	177	8.0%	13	18	18	13
	49,987	195	9.3%	16	22	24	14
	57,433	210	9.9%	18	26	26	20
	65,258	204	9.2%	19	24	28	17
	72,563	194	9.3%	17	19	23	14
	80,004	209	9.9%	15	19	22	13
	87,635	166	7.7%	11	16	17	14
	95,219	175	8.1%	12	22	15	18
	102,843	182	8.4%	12	19	12	13
	Average	185	8.7%	18	21	20	20

Table 10

Oil Analyses from Escorts							
Vehicle Number	Odometer (miles)	Mn Found (ppm)	As % Mn Expected (%)	Fe Found (ppm)	Cu Found (ppm)	Pb Found (ppm)	Si Found (ppm)
317	14,723	5		19	37	17	44
	22,135	3		17	24	19	29
	30,576	2		27	24	27	25
	37,446	1		28	23	25	17
	44,969	1		25	23	23	16
	52,056	1		21	28	28	17
	60,001	0		19	26	25	21
	67,827	0		21	22	26	19
	74,865	0		14	18	19	14
	82,444	0		14	20	23	15
	90,665	0		18	20	16	19
	97,500	0		17	18	11	17
	Average	1		20	24	22	21
318	17,720	50	1.7%	77	74	32	248
	24,976	147	7.1%	24	31	24	71
	32,374	160	7.6%	19	27	22	61
	40,164	152	6.9%	14	20	19	34
	47,418	148	7.2%	14	19	19	28
	55,072	166	7.6%	15	20	21	25
	62,978	195	8.7%	14	18	23	19
	69,951	198	10.0%	15	24	22	21
	77,260	177	8.5%	14	20	18	14
	85,218	197	8.7%	19	18	20	13
	92,452	204	9.9%	15	19	17	13
	100,243	201	9.1%	16	19	17	10
	107,496	207	10.0%	15	23	16	10
	Average	169	7.9%	21	26	21	44

Table 11

Regulated Emissions from Explorers									
Vehicle Number	Odometer (miles)	Correlation Cell				Particulate Cell			
		HC g/mi	CO g/mi	NO_x g/mi	No of Tests	HC g/mi	CO g/mi	NO_x g/mi	No of Tests
304	55,000	0.548 ±.061	3.242 ±.206	0.200 ±.008	6	0.467 ±.059	3.513 ±.753	0.207 ±.007	2
	105,000	0.887 ±.101	5.572 ±.305	0.221 ±.011	6	0.880 ±.012	6.166 ±.279	0.287 ±.022	2
305	5,000	0.120 ±.008	1.840 ±.184	0.118 ±.015	6	0.126	1.898	0.139	1
	20,000	0.119 ±.004	2.228 ±.146	0.141 ±.012	6	0.113	1.974	0.190	1
	55,000	0.154 ±.005	3.596 ±.252	0.131 ±.008	6	0.152 ±.017	3.383 ±.305	0.190 ±.009	3
	85,000	0.168 ±.012	4.151 ±.098	0.163 ±.014	4	0.187 ±.017	n.a.	0.161 ±.003	3
	105,000	0.197 ±.007	4.512 ±.260	0.217 ±.013	6	0.214 ±.001	4.918 ±.417	0.226 ±.004	2
306	5,000	0.142 ±.010	1.812 ±.113	0.106 ±.009	6	0.147	1.735	0.123	1
	20,000	0.172 ±.015	2.279 ±.141	0.078 ±.009	6	0.176	2.775	0.153	1
	55,000	0.173 ±.016	1.734 ±.125	0.314 ±.056	6	0.188 ±.023	2.058 ±.227	0.334 ±.008	2
	85,000	n.a.	n.a.	n.a.	n.a.	0.672 ±.044	5.834 ±.204	0.213 ±.015	2
	105,000	0.656 ±.020	5.862 ±.065	0.175 ±.013	6	0.666 ±.078	5.729 ±.080	0.186 ±.017	3
307	55,000	0.353 ±.034	4.709 ±.377	0.178 ±.019	6	0.306 ±.028	4.315 ±.325	0.156 ±.003	2
	105,000	0.383 ±.008	6.186 ±.195	0.143 ±.015	6	0.429 ±.048	7.168 ±.820	0.151 ±.014	3

Note: standard deviations are shown; the correlation and particulate cells used EEE and durability fuels, respectively.

Table 13

Effect of MMT on Toxic Emissions								
Vehicles Odometer miles	**Formaldehyde**		**1,3-Butadiene**		**Benzene**		**Toluene**	
	MMT mg/mi	**With out mg/mi**	**MMT mg/mi**	**With out mg/mi**	**MMT mg/mi**	**With out mg/mi**	**MMT mg/mi**	**With out mg/mi**
Explorers #306,#305 5,000	0	1	n.a.	0.3	n.a.	4.3	n.a.	14.7
20,000	0	0	0.6	0.3	9.1	3.1	12.7	6.8
55,000	2	1	0.7	0.6	7.2	6.1	11.3	9.4
85,000	1	0	1.5	0.6	43.3	7.1	50.4	17.3
105,000	3	0	1.2	0.9	35.7	9.5	41.7	13.9
Escorts #316,#315 5,000	0	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20,000	2	1	1.3	0.4	17.8	10.4	13.5	8.7
55,000	0	2	1.8	0.4	18.9	8.6	12.0	11.9
85,000	0	0	1.8	1.5	19.2	18.4	12.4	13.4
105,000	1	0	2.1	0.9	20.5	14.2	12.9	12.6

Table 12

Regulated Emissions from Escorts

Vehicle Number	Odometer (miles)	Correlation Cell HC g/mi	Correlation Cell CO g/mi	Correlation Cell NO_x g/mi	Correlation Cell No of Tests	Particulate Cell HC g/mi	Particulate Cell CO g/mi	Particulate Cell NO_x g/mi	Particulate Cell No of Tests
315	5,000	0.092 ±.011	0.832 ±.073	0.298 ±.030	6	0.113	0.741	0.190	1
	20,000	0.146 ±.029	1.397 ±.421	0.327 ±.053	6	0.183 ±.006	0.937 ±.017	0.302 ±.031	2
	55,000	0.184 ±.020	1.944 ±.338	0.384 ±.034	6	0.195 ±.021	1.203 ±.014	0.333 ±.025	2
	85,000	n.a.	n.a.	n.a.	n.a.	0.277 ±.017	2.242 ±.130	0.397 ±.016	2
	105,000	0.174 ±.015	2.095 ±.357	0.447 ±.023	6	0.266 ±.057	2.122 ±.170	0.463 ±.039	3
316	5,000	0.088 ±.009	0.840 ±.155	0.249 ±.029	6	0.178	1.373	0.264	1
	20,000	0.161 ±.019	1.488 ±.210	0.303 ±.026	6	0.211 ±.043	1.326 ±.340	0.280 ±.061	4
	55,000	0.332 ±.096	2.116 ±.550	0.386 ±.047	6	0.239 ±.002	1.290 ±.031	0.452 ±.039	2
	85,000	n.a.	n.a.	n.a.	n.a.	0.354 ±.004	2.052 ±.156	0.553 ±.006	2
	105,000	0.312 ±.027	2.325 ±.408	0.448 ±.025	6	0.368 ±.048	1.727 ±.050	0.452 ±.030	3
317	55,000	0.189 ±.020	1.708 ±.219	0.396 ±.035	6	0.171 ±.016	1.132 ±.087	0.429 ±.023	2
	105,000	0.177 ±.018	2.433 ±.467	0.521 ±.030	6	0.210 ±.006	2.130 ±.015	0.574 ±.022	3
318	55,000	0.327 ±.019	1.687 ±.139	0.462 ±.019	6	0.451 ±.011	2.050	0.479 ±.017	2
	105,000	0.323 ±.041	2.911 ±.604	0.509 ±.024	6	0.355 ±.008	2.175 ±.043	0.538 ±.011	3

Note: standard deviations are shown; the correlation and particulate cells used EEE and durability fuels, respectively.